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Making Sense of Document Collections with Map-Based Visualizations

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A thesis submitted in partial fulfillment of the requirements for the degree in Doctor of Philosophy

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by

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Abstract

As map-based visualizations of documents become more ubiquitous, there is a greater need for them to support intellectual and creative high-level cognitive activities with collections of non-cartographic materials — documents. This dissertation concerns the conceptualization of map-based visualizations as tools for sensemaking and collection understanding. As such, map-based visualizations would help people use georeferenced documents to develop understanding, gain insight, discover knowledge, and construct meaning.

This dissertation explores the role of graphical representations (such as maps, Kohonen maps, pie charts, and other) and interactions with them for developing map-based visualizations capable of facilitating sensemaking activities such as collection understanding. While graphical representations make document collections more perceptually and cognitively accessible, interactions allow users to adapt representations to users' contextual needs. By interacting with representations of documents or collections and being able to construct representations of their own, people are better able to make sense of information, comprehend complex structures, and integrate new information into their existing mental models. In sum, representations and interactions may reduce cognitive load and consequently expedite the overall time necessary for completion of sensemaking activities, which typically take much time to accomplish.

The dissertation proceeds in three phases. The first phase develops a conceptual framework for translating ontological properties of collections to representations and for supporting visual tasks by means of graphical representations. The second phase concerns the cognitive benefits of interaction. It conceptualizes how interactions can help people during complex sensemaking activities. Although the interactions are explained on the example of a prototype built with Google Maps, they are independent of Google Maps and can be applicable to various other technologies. The third phase evaluates the utility, analytical capabilities and usability of the additional representations when users interact with a visualization prototype – VIsual COLlection EXplorer. The findings suggest that additional representations can enhance understanding of map-based visualizations of library collections: specifically, they can allow users to see trends, gaps, and patterns in ontological properties of collections.

Keywords: Digital libraries; Human-information interaction; Information visualization; Interaction Design; Map-Based Visualizations; Sensemaking; Collection Understanding; Representations; Ontological Properties; Digital Maps; Geolibraries; Next Generation Library Catalogues; Geovisualization; Georeferencing

Co-authorship statement

I was primarily responsible for the research presented in this dissertation, including conceptualization, study design, data collection, analysis, and manuscript preparation. The conceptualizations presented in Chapters 3 and 4 were written with the guidance and assistance of Dr. Sedig. They were submitted for publication as co-authored papers, with myself as the primary author. For the study presented in Chapter 5, I designed the study, collected the data, analyzed the data, and prepared the manuscript with the help of Dr. Sedig. The study will be submitted for publication as a co-authored paper. Dr. Sedig has read this statement and is in agreement with it.

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As with every dissertation there are many people who provided various forms of guidance, assistance, and encouragement. It is difficult to overstate my gratitude to my supervisor, Dr. Kamran Sedig, for directing me along this particular line of research, and remaining patient with me throughout. His editorial advice and precise sense of language was essential to the completion of this dissertation and clearing the path towards thesis completion in his solution-oriented way. I am also thankful to him for carefully reading and commenting on countless revisions of this manuscript. He has taught me innumerable lessons and insights on the workings of academic research in general. I could not have written this dissertation without his support.

The topic of this dissertation would not have been possible without the research done by the pioneer in geodigital libraries – Dr.Linda Hill. As someone who once worked in the field, I have deep respect and fondness for her work on merging text with coordinates, georeferencing, and building one of the largest gazetteers in the world. I had many energetic and challenging conversations with Dr. Linda Hill regarding the role of gazetteers in map-based visualizations. These discussions helped me better understand the gaps in the research on geodigital libraries.

For this dissertation I would also like to thank my reading committee members: Dr. Victoria Rubin and Dr. Grant Campbell for their time, interest, and helpful comments. I am indebted to Dr. Victoria Rubin, who as a good friend, was always willing to help, give her best suggestions, encouragement, support, and her willingness to discuss ideas at their initial stage.

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I have also been fortunate in that the many members of staff at the libraries with whom I have had contact have willingly shared their knowledge and skills. It is not possible to list all of these people here but I would like to acknowledge the work of the librarians at the Graduate Resource Center at The Faculty of Information and Media Studies, Slavic librarian-emerita Wanda Wawro at Cornell University Library, reference librarian Regina Frakowiac and collection developer Grant Harris at the Library of Congress. They helped tremendously with the search for all sorts of materials and understanding user tasks and activities in Slavic collections. A special thank also goes to Slavic cataloguers and collection developers at the Library of Congress who build such an outstanding collection of Local History of Ukraine which I used for visualization in this dissertation.

I am also indebted to the many countless contributors to the "Open Source" programming community (especially Mike Williams for his unofficial Google Maps API tutorial and countless contributors to Google Maps listserves) for providing the numerous tools, systems, and tutorials I have used to develop the prototype visualization for this thesis. The entirety of my thesis has been completed using such technologies and tutorials, and I consider it to have been an enormous benefit. Thank you, keep up the good work.

I am deeply appreciative to the Faculty of Information & Media Studies for funding me throughout the years and allowing me take leave of absence to take care of my daughter who was born midway through this project.

Leaving the personal until last, I would like to thank those closest to me, whose presence helped make the completion of my graduate work possible. My appreciation goes to my friend Carol Hempstead for the words of encouragement and for helping me out with proofreading and catching my typographical errors. I would also like to thank my family for all their love and encouragement. I would like to express my heart-felt gratitude to my parents and my husband’s parents for their faith in me, allowing me to be as ambitious as I wanted, helping with kids, and unconditional support. Most of all I am thankful for my loving, supportive, encouraging, and patient husband Alex who in love and companionship had, at times, to live with this thesis as much as me. His faithful support during these years is much appreciated. I am also grateful to him for being my personal computer administrator who maintained the server so efficiently that I never had to worry about viruses, losing files, creating backups or installing software. Thank you.

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Chapter 1: Introduction

1.1 Motivation

The topic of this dissertation was inspired primarily by the research exploring the relationship between graphical representations and text. The relationship between graphical representations and text has a long history that spans thousands of years. Chronologically graphical representations preceded text representations. Early forms of representations such as pictograms (or pictographs), ideograms, petroglyphs, and mandorlas were used in ancient societies to communicate concepts, objects, activities, places, events, ideas, symbols, or rituals because people did not know how to relay messages in any other way. These early representations were precursors of writing. With the invention of writing, however, graphical representations had to yield to writing systems because their communicative power was considered much weaker. Text representations appeared to be far more superior for "presenting correlations and for producing arguments based on them" (Neurath, 1996, p. 328), explaining something in detail. Unlike text, graphical representations could not render smells, noises, and feelings, and often could not be understood universally, but only in relation to a specific context, cultural background, and the previous experience of the perceiver (Neurath, 1996), and therefore were considered inferior to written text.

But nowadays due to unprecedented overproduction of textual information, history makes a U-turn and re-evaluates the role of graphical representations. Research in various disciplines demonstrates that despite limitations and shortcomings, different forms of graphical representation such as maps, images, diagrams, graphs, and symbols can aid cognition to handle large volumes of information more efficiently than text. For example, geographic maps can scaffold users in cognition of geographic space. Without maps, users' mental models of geographic locations are imperfect. They have distortions (holes, folds, tears, and cracks). Users have problems remembering distances and shapes (e.g., short distances are overestimated and long distances are underestimated; curves are often remembered as straighter than they actually are) (Tversky, 1981). Maps help users overcome such imperfections. What concerns images, everyone knows that pictures are worth a thousand words. Otto Neurath, an Austrian educator and sociologist, saw images as having a longer life and greater impact especially at the first stage of getting new knowledge (Jansen, 1996). Diagrams help people externalize their problems (DeLeeuw & Hegarty, 2008), reduce complexity and amplify cognition; they help in understanding causal relationships, categorizing and organizing information (Burkhard, 2004; Chen, 1996). Graphs provide excellent aid for making comparisons or visualizing relationships (Scragg, 2000; Peebles & Cheng, 2001; Harris, 1999), enhancing visual and retrieval tasks (Spoerri, 2004), and knowledge construction (Shah, Mayer, & Hegarty, 1999). Expressing knowledge through symbols may facilitate the transfer of learned knowledge to novel situations (Sloutsky, Kaminski, & Heckler, 2005). Symbols have been used for augmenting information retrieval and helping users to discriminate relevant documents from non-relevant (Hearst, 1995; Korfhage, 1991; Hemmje, Kunkel, & Willett, 1994; Spoerri, 2006).

While there is no doubt that graphical representations can support synthesis of text information, the translation from text to representations is problematic. The majority of translational mechanisms have been well-established for quantitative data (see, e.g., Tukey, 1988), not text. History of library and information science, however, has witnessed several attempts to represent language with representations. One of the first people who utilized graphical representations for linguistic categories was Otto Neurath. He designed a method, The Vienna Method of Picture Statistics, which he used to develop an international visual language the International System of Typographic Picture Education (known as ISOTYPE) (Chapel, 1996). In 1923 he published nearly two thousand pictographs, which personify coloured little men of different professions, cities, houses, boats, automobiles, and so forth. These pictographs were meant to be used for communication of statistical information between nations and for education of the illiterate (Breitenstein, 2006; Dalbello & Spoerri, 2006). Later attempts were based on statistical techniques. Among such techniques are vector-space model, dimension reduction techniques (e.g., multidimensional scaling, self-organizing maps, latent semantic indexing), layout algorithms (e.g., energy minimization/force-feedback models) (Börner, Chen, & Boyack, 2003; Friendly, 2000; Fabrikant & Buttenfield, 2001). The aim of the majority of these algorithms is to obtain macro views of collections of text, showing the relative positions and relationships among major topics, and to display large amounts of data in a limited space. However, many of these approaches have shortcomings. ISOTYPE pictographs are regarded outdated, old-fashioned, and difficult-to-interpret (Holmes, 2001); statistically-generated representations are often criticized for not being cognitively-plausible (Fabrikant & Buttenfield, 2001; Chen & Börner, 2002; Ancona, Freeston, Smith, & Fabricant, 2002; Fabrikant, Montello, Ruocco, & Middleton, 2004).

The key problem with translating text to graphics is that information in text is multifaceted and culture-and language-dependent. Text has different ontological properties which can be represented with different representations. For example, geographic concepts can be best understood in the context of maps; other subjects, in the context of trees or Kohonen maps; and so on. In addition, text properties and representations vary from culture to culture and from language to language. For this reason, there are many unanswered questions regarding representations: How can they work together? How can they be used to represent different collections of text in different languages?

My interest in representations has later merged with the need to extend the range of tasks and activities with graphical representations. This research direction was formulated in the early 1990s by the pioneer in geographic information retrieval Dr. Linda Hill (1990). Despite the fact that the need was realized more than 20 years ago, the tasks of library users are still narrowed down to tasks facilitating the work at the level of a single document (i.e., searching, browsing, navigating, and identifying). Such tasks are typical for text representations. However, the transition from text to graphical representations predisposes users to work with large volumes of information and to make sense of large document collections, not single documents. At this level, people engage in higher-order cognitive activities such as sensemaking, visual analysis, and other activities. How can these higher-level cognitive activities be conceptualized and translated to interactions with maps and other graphical representations is the question that this dissertation aims to answer. Even though the second generation digital maps such as Google Maps are equipped with rich interactions (zooming, panning, navigation, browsing, and others), conceptualization of interactions opens up a Pandora's box of issues associated with choosing the right interaction techniques for specific tasks: there simply is no good prescription for designing an effective dialogue between humans, text, Google Maps, and other representations. Moreover, there is a lack of evaluation proving the efficiency of certain interactions in support of specific tasks and activities. As a result, we have an opportunity and a need for interdisciplinary research to bridge this gap. I believe that my background in library and information science, working experience at the Alexandria Digital Library, one of the first geodigital libraries, and extensive readings in information visualization and geovisualization have put me in a unique position to undertake research about representations, interactions, and tasks for defining a framework for visualizing text on Google Maps.

1.2 Objectives

In this dissertation, I am considering a special instance of text - Knowledge Organization Systems (KOS) such as metadata and classifications and a special instance of graphical representations – digital maps such as Google Maps. In particular I am investigating the phenomenon of georeferences in KOS. KOS in library catalogues are imbued with indirect georeferences (Petras, 2004; Buchel, 2006; Hill, 2006). Indirect georeferences are references to geographic locations in a form of subjects, terms, or other linguistic representations. Linguistic representations of georeferences have many pros and cons.

Among their advantages is that they can facilitate text retrieval; and they can help with an understanding of hierarchical relationships among geospatial concepts. But at the same time, linguistic representations have many shortcomings since they cannot show many spatial locations and relations simultaneously (Uttal, Fisher, & Taylor, 2006); and therefore cannot help users derive geospatial patterns, trends, and relationships (Card, Mackinlay, & Shneiderman, 1999; Spence, 2001; Peuquet, 2002). Language by nature is categorical and is more reliable for conveying categorical spatial relations (e.g., is part of Ontario) than exact ones (such as metric or coordinates) (Leibowitz, Guzy, Peterson, & Blake, 1993; Hill, 2006) but which are critical for spatial reasoning and thinking. Besides this, the linear nature of language is ill-suited for representing higher dimensionality of spatial information which is commonly characterized by four dimensions: longitude, latitude, altitude, and time (Peuquet, 2002).

To make geospatial locations and relationships more salient and meaningful, georeferences need to be put in the context of map-based visualizations. This is the primary goal of this dissertation. While previous research has investigated how to map georeferences (Buckland, Chen, Gey, Larson, Mostern, & Petras, 2007; Hill, 2006; Zerneke, Buckland, & Carl, 2006) and how to automatically geocode KOS (Freire, Borbinha, Calado, & Martins, 2011), this dissertation takes a broader approach and investigates not only how to put georeferences on a map, but how to design maps that can help people think, understand, and perform higher-order cognitive activities with KOS such as sensemaking, visual analysis, problem solving, knowledge discovery, and so on. Higher-order cognitive activities are very difficult to conceptualize, since to date there are no prescriptions on how to disassemble activities with information into smaller, simpler tasks such as searching or checking out a book at a library, because besides tasks such activities also include many cognitive processes the support for which is difficult to provide programmatically. There are some general models of such activities (see, e.g., in Pirolli & Card, 2005), but it is not easy to interpret how such models can be applied in the context of KOS.

Furthermore, putting KOS on a digital map adds a host of issues associated with the granularity of knowledge represented in KOS. While georeferences alone can be described in four dimensions, the number of dimensions in KOS is uncertain and can be very large; each of these dimensions can have representations; whereas different representations can support different tasks.

The investigation in this dissertation took a multidisciplinary approach. Various design components were drawn from studies on geovisualization, information visualization, and digital libraries. Ideas about conceptualization of tasks and activities were drawn from studies on cognition, human computer interaction (HCI), geovisualization, information visualization, and library and information science (LIS). By taking a multidisciplinary approach, novel ideas were generated that would otherwise be left out if the investigation was focused on one aspect of the problem (e.g., georeferences). According to Monk and Gilbert (1995, p.8) multidisciplinary research can only be "effective when it involves the creative juxtaposition of different approaches around a specific problem, so that each can shed its own light on the issues." This strategy had a significant impact on this dissertation. Rather than focusing research efforts only on the LIS domain to solve this complex problem, the research integrated and culminated collaborative efforts involving many disciplines.

1.3 Structure of the Dissertation

Chapter 2 provides background information about the core concepts necessary to understand this dissertation: ontological properties, georeferences, representations of ontological properties, and interactions. After the background chapter, the dissertation is organized as a collection of articles, each presented as a separate chapter. In spite of the dissertation being organized as a collection of articles, and not as a monograph, the chapters share several theoretical and empirical properties and follow a logical sequence with each chapter building on the previous one. The findings in the articles, separately and taken together, contribute to the understanding of the role of KOS in the design of representations and interactions in map-based visualizations, and to the role of interactions and representations in facilitating sensemaking activities. As a result, each chapter includes its own introduction and background material, as well as its own list of references. The articles are presented as they appeared at the date for submission. The article in Chapter 3 was published in May, 2011 issue of the Knowledge Organization journal. The article in Chapter 4 is under review in Information Research Journal. The article in Chapter 5 has been submitted to the Journal of Digital Information.

The first two articles present conceptualizations to guide the design of map-based visualizations as tools for sensemaking. The *first conceptualization* (Chapter 3) explains the role of additional graphical representations in facilitating elementary and synoptic visual tasks. This conceptualization brings together research findings on the utility of additional representations from the research on digital libraries, geovisualization, and information visualization. The *second conceptualization* (Chapter 4) describes a methodology for designing interactions suitable for facilitating higher-order cognitive activities such as sensemaking. Despite a common view that interactions do not directly contribute to understanding, this chapter explains how interactions can simplify and augment sensemaking activities incrementally by helping people prepare documents and information in documents for visual tasks and ultimately higher-level sensemaking. This conceptualization brings together research findings on interactions from a wide range of research fields, including digital libraries, human-computer interaction, information visualization, and to a lesser degree, cognitive science. All examples in both conceptualizations are illustrated with the prototype - Visual COLlection EXplorer (VICOLEX) – designed for facilitating an understanding of a Local History collection from the Library of Congress catalogue. The third article (Chapter 5) assesses the ability of additional representations and selected interactions in VICOLEX to support collection understanding. Basically, it explores the utility of the first, and partially the second conceptualizations. The dissertation concludes with a summary of the major contributions and future research opportunities.

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Chapter 2: Background

This chapter provides background information about core concepts necessary to understand the remaining chapters in this dissertation. Specifically, this chapter introduces such concepts as ontological properties, knowledge organization systems, representations, interactions, visual tasks, sensemaking activity, and discusses the limitations of the existing map-based visualizations of library collections.

Libraries deal with many physical and abstract objects. These objects are documents, geographic placenames, author names, subjects, and so on. Out of all these objects, documents are the most significant ones; the rest are supplementary and support the organization of the former. Each object has its own ontological properties. For instance, the ontological properties of a document may include its author, title, publisher, height, number of pages, illustrative matter, indexical information, publication language, subject, edition information, and publication date. Libraries differentiate as many as 2000 descriptive properties of published materials, out of which only 70-107[1] are regarded as the most common ones.

In this dissertation, the descriptive properties in MARC are referred to as ontological because they are explicit specifications of document conceptualization that define the vocabulary that describes the concepts and the relations among them. According to Gruber (1993), such specifications comprise ontologies. Treating metadata properties as ontological is not uncommon. Other researchers and practitioners also view metadata standards as ontologies (see, e.g., Jacob 2003, Nogueras-Iso, Zarazaga-Soria, & Muro-Medrano, 2005; Tsouvaras, 2008).

Some of the ontological properties of publications are geospatial properties, recorded in metadata either explicitly (in the form of geospatial coordinates) or implicitly (in the form of placenames,

[1] These statistics are based on the recent study of MARC metadata (Moen & Miksa, 2007). The reference is made to Tables 13 and 14 of this report, where common elements of LC-created and non-LC created records are listed.

standard numbers, or geographic codes) (Hill, 2006). These geospatial properties are the focus of this dissertation, since only they have absolute locations suitable for map-based visualization and provide an additional type of access to documents. Although not all geospatial properties in MARC have coordinates which are necessary for map-based visualizations, this dissertation does not limit itself to assigning coordinates to implicit georeferences, since this problem has been resolved by other researchers (Freire, Borbinha, Calado, & Martins, 2011), instead it focuses on visualizing ontological properties of documents.

Properties of various objects are captured in corresponding Knowledge Organization Systems (hereafter abbreviated as KOS): gazetteers, authority records, and classification schemes (Hill, Buchel, Janee, & Zeng, 2002; Zeng, 2008). Thus, properties of publications are described in item-level metadata records (also known as bibliographic records); properties of placenames in gazetteer records; properties of authors in authority records; and properties of subjects in classifications. Commonly, KOS are characterized by rich content and reside outside of the collections of objects. They contribute controlled sets of labels for concepts, authors' names, etc; definitions; relationships that can be used to translate between equivalent terms and support navigation using these relationships. This dissertation extends the notion of KOS to item-level metadata standards such as MARC. Although MARC is distinct from other content-containing KOS objects, such as the Getty Art & Architecture Thesaurus, which are used to populate the fields in a particular MARC record, it has rich content and is used to organize knowledge similar to other KOS schemes. For this reason, MARC is treated as a special form of KOS.

In the context of information systems, KOS can have multiple representations, in the form of text, call numbers, glyphs, and others. The most common representations of existing KOS, however, are in a form of text. Although text representations are capable of supporting various searching tasks; they are less suitable for making sense about geographically distributed KOS collections and facilitating geospatial access to georeferenced collections. For example, text is ill-suited for making sense of subjects, time periods, languages, book sizes, places of publication, and authors in collections about various geographic locations. It does not easily give answers to the following types of questions: Which collection has more books in English or French? Which collection has more books published in 2011: Toronto or Montreal? Text also precludes users from distinguishing commonalities and idiosyncrasies of KOS. According to Tufte (1990) text is also unrevealing of complex structures and relationships. As a result, KOS are often caught up in the endless "flatland" of text. In such a "flatland," it is difficult to focus on groups of records, instead records have to be reviewed one at a time (Veerasamy, 1997).

However, there exist many other alternative representations for different ontological properties of KOS. For example, subjects can be represented as a ThemeScape (Wise, et al., 1995), Kohonen Map (Kohonen, 1995), Tree Map (Shneiderman, 1992), Topic Map (Weerdt, Pinchuk, & Aked, 2007; Le Grand & Soto, 2002), Flickr-Style Tag Cloud (Bausch & Bumgardner, 2006), Cartogram (Keim, North, Panse, & Schneidewind, 2003), Fisheye View (Furnas, 1986), or Hyperbolic Tree (Lamping, Rao, & Pirolli, 1995).

The best representations for geospatial properties of KOS are digital maps (Hill, 2006). Maps make the invisible visible, and facilitate understanding of things that are not easy (or sometimes even impossible) to see in the real world or perceive directly through other senses (Edsall, 2001). Maps make geospatial locations, spatial clusters, outliers, relationships among geospatial concepts, and geographic proximity perceptually salient and expedite visual search for relevant information (Peuquet, 2002). Unlike text, maps can help users understand what locations are represented in collections, what is their density, how big are geographical distances among collections, how collections are distributed in space and time.

The advantage of maps has been well-understood by geodigital libraries. Many of them use map-based visualizations as interfaces for their collections (Buchel & Hill, 2009). Among the first adopters of map-based visualizations were map libraries: the Georeferenced Information Network project, the CARTO-NET project, some projects at the British Library (Hill, 2006), and the Alexandria Digital Library[2](ADL) at the University of California, Santa Barbara.

But the early map-based visualizations of library collections have many shortcomings. For instance, their functionality is often limited to spatial browsing and searching. Spatial browsing allows users to select documents on a map (Larson, 1996). Spatial searching facilitates retrieval by geographical location, placename, or subject theme (Panel on Distributed Geolibraries, National Research Council, 1999). The representations of documents on such maps take forms of footprints or icons (e.g., image thumbnails, markers, balloons, prisms, graduated circles, 3D spatial histograms of dataset counts, stacks, and differently-shaped coloured blocks) (Ancona, Freeston, Smith, & Fabricant, 2002; Ahonen-Rainio & Kraak, 2005). As such visualizations encode only documents and their quantities. The most advanced interfaces allow interacting with documents in space and time (see Zerneke, Buckland, & Carl, 2006). Perseus Digital Library[3] at Tufts University and Electronic Cultural Atlas Initiative[4] have such interfaces. This dissertation argues that even the most advanced map-based visualizations of library collections lack proper support for understanding ontological properties.

The literature on geovisualization is replete with suggestions about information visualization techniques that can make map-based visualizations more engaging, useful, comprehensible, and cognitively-plausible. Here are just a few examples. Pequet (2002) suggests improving geobrowsing with images that "spark imagination" and various map interactions that aid users "to see emergent

[2] http://www.alexandria.ucsb.edu/

[3] http://www.perseus.tufts.edu/

[4] http://ecaimaps.berkeley.edu/clearinghouse/

features." Fabrikant & Buttenfield (1997) propose to enhance browsing in map-based visualizations with direct manipulation, coordinated windows with dynamic queries, and sliders. Ahonen-Rainio & Kraak (2005) report the utility of additional representations in decision making about relevance of datasets.

Moreover, there exists empirical evidence that many of these visualization techniques have positive effects on activities, tasks, and human cognition. Additional representations that complement maps in a coordinated multiple view visualizations have been proven to be useful for knowledge discovery, hypothesis generation, data mining, and visual analysis in different subject domains, contexts, and spheres of human activities. Improvise visualization, for example, helped users reveal regular and irregular periodic visitation patterns of guests at two hotels in central Pennsylvania from 1894 to 1900 (Weaver et al., 2007). The visualization approach for cancer data analysis described in (Guo, Gahegan, MacEachren, & Peuquet, 2003; Guo, Gahegan, MacEachren, & Zhou, 2005) offered insights about unknown patterns related to cancer. Additional representations such as self-organizing maps enhanced extraction of properties, clustering, exploration, and knowledge discovery in the visualization prototype described in (Koua, 2005).

The design of semantically-rich representations has been widely researched in information visualization, cartography, and geovisualization. For example, Chernoff (1973) suggested using facial features to represent multiple variables of k-dimensional data. Tufte (2001) developed principles of graphical excellence. One of his principles is that graphical representations should give the viewer the greatest number of ideas in the shortest time with the least ink in the smallest space. Spence (2007) defined principles of design of multidimensional icons. In addition, a sizable body of research exists on the utility of multiple representations. Combining representations (or multiple views) can support the performance of specific tasks (Whitby, 1996). For instance, many visualization applications today are being developed in the form of purpose-specific packets that include a number of representations. Such packets can include maps, charts, self-organizing maps, and diagrams. According to Tufte (2001), multiple representations can facilitate quantitative and comparative reasoning and convey information through repetition by making small changes salient. “[M]ultiples work as efficient and convincing summaries of data or an argument…” (Tufte, 1990, p. 30).

Another important aspect that should not be ignored in the design of map-based visualizations is that static, non-interactive representations are not always effective in facilitating tasks and activities (Spence, 2007). This is especially true for maps, because maps are complex representations that have multiple layers and encodings. The literature on cognitive psychology shows that in order to deal with complex imagery such as maps, people often use selective attention, apply spatial filters, suppress the distracters and unattended information, and select targets (Astle, Scerif, Kuo, & Nobre, 2009; Yang, Yuan, & Wu, 2007; Mozer, 1991; Luck & Hillyard, 1994; Thorpe, Fize, & Marlot, 1996; Desimone & Duncan, 1995; Lueschow, Miller, & Desimone, 1994; Van Essen & Deyoe, 1995; Ullman, 1996; Moran & Desimone, 1985).

To be useful, representations need to afford interactions, otherwise much of their semantic and relational properties remain hidden and latent (Sedig & Sumner, 2006). In the context of this dissertation, interactions refer to the actions that are performed on representations, and the subsequent responses of those representations to those actions (Sedig & Sumner, 2006; Sedig & Liang, 2006). In other words, interactions refer to “how people physically act on the environment and how the environment responds” (Fast & Sedig, 2005). Interactions allow users to perform actions such as arranging, navigating, zooming, chunking, annotating, composing, cutting, filtering, fragmenting, and probing (Sedig & Sumner, 2006). They enable users to transform data by adding or subtracting attributes, filtering in and out subsets of the data, and answering what-if questions through manipulations and communication, drilling-up, and drilling-down (Fayyad, Grinstein, & Wierse, 2002).

Interactions act as extensions of static representations by making them dynamic, allowing their latent meanings to become visible (Sedig & Liang, 2006), and by allowing users to adapt the visual information according to their needs (Sedig, 2009) and to offload some of their cognitive processes onto the computer (Sedig, Rowhani, & Liang, 2005).

Interactions also facilitate the conversion of information into knowledge. Knowledge does not exist on its own. It is information that has been made sense of through human interaction with that information; or in other words, information that has been processed (Buckland, 1991; Allen, 1996). Knowledge is a process by which a user acts upon a body of information, interprets it, and integrates it into his/her existing knowledge structures and schemata. As such, interaction can be viewed as the mechanism that facilitates the discovery of latent elements and features of information, allowing users to form mental models and understanding of the information, and, hence, supporting the knowledge construction process.

Interactions, here, are narrower in scope than tasks or activities. They refer more to how people perform low-level actions to carry out those higher-level tasks and activities. Tasks and activities refer more to what people do with KOS. Consider, for example, the task of browsing books on bookshelves in library stacks. The activity is browsing. Accomplishing this activity involves many actions such as walking to the stacks, focusing on the books on the shelves, comparing their sizes, covers, languages of publications, reading titles and years on the spines of the books, opening interesting books, reading summaries inside the books, looking at the index or the table of contents, and so forth. However, it is important to note that interactions with representations should not always be the same as actions performed on real world objects. For example, the described activity of browsing the bookshelves in a library setting is not the same as browsing books by call numbers in an online public access catalogue.

In online catalogues, users are presented with a list of items sorted by call number, where each item can be probed by clicking on a hyperlink.

Interactions with map-based visualizations of documents are commonly limited to zooming and panning. Users can zoom into various layers, focus onto geographical locations at different levels of abstraction, navigate between different layers, and pan the map by dragging it to different locations. Tasks with KOS[5] encompass finding, identifying, selecting documents, and acquiring or obtaining access to documents (Svenonius, 2000). To visualize KOS on digital maps, digital library researchers have merged KOS tasks with map interactions and geographic retrieval. As a result, map-based visualizations of library collections support two fundamental tasks related to library collections and geographic information retrieval – searching and browsing. The goal of this dissertation is to understand how these tasks can be expanded. Some information behaviour models suggest that users' interactions with information encompass many other tasks. For example, users monitor, differentiate, extract, and verify information (Ellis, 1989; 1993), select, explore, and formulate (Kuhlthau, 1991). Each of these tasks might require a series of interconnected searches. For example, monitoring information might require searches about the subject in various geospatial locations, analysis and interpretation of results. These more complicated tasks indicate that interactions with KOS usually facilitate only a single aspect of a bigger problem, which is sensemaking. Therefore, focusing on these tasks may be short-sighted (Qu & Furnas, 2005). This dissertation is aimed at understanding sensemaking activities.

Sensemaking consists of an interlocking set of different types of subtasks such as searching for representations, encoding information in them to answer task-specific questions and to reduce the cost of operations, information seeking, filtering, categorizing, comparing, synthesizing, aggregating and scaling, identifying a critical subset, assessing, interpreting, and so on (Qu & Furnas, 2005; Russel,

[5] Which are known in librray science as bibliographic objectives or bibliographic tasks.

Stefik, Pirolli, & Card, 1993; O'Day & Jeffries, 1993). The purpose of sensemaking is to establish the goals of the task and to discover a problem's structure, "texture" (i.e., vocabulary, and available documents), questions that should be asked, and how the answers are to be organized (Russel et al., 1993). Sensemaking takes place when people face ill-defined situations, where their current knowledge is insufficient (Dervin, 1992). Users' conceptualizations of a problem and their search strategies gradually evolve during sensemaking. While users make sense of information, they discover missing pieces, changes in information, or something interesting which triggers revisions in strategies and understanding of the problem.

Most of the time in sensemaking is consumed by extraction of information. According to previous studies (Russell et al., 1993), extraction of information can be optimized by suitable representations which answer task-specific questions, capture salient features of the data, and help users discover the topic structure and texture. External representations can help users conceptualize a problem at hand and form mental models. Qu & Furnas (2005) and O'Day & Jeffries (1993) suggest that external representations can be derived from the information sources themselves. For example, documents frequently have tables of content or structured abstracts that reveal their structure and content. Tables of content and abstracts can be used as external representations.

Besides retrieving, sensemaking, and information extracting, map users also engage in visual tasks. While retrieval and bibliographic tasks can be delegated to a computer, visual tasks are performed by users. How well map-based visualizations support visual tasks depends not only on designer's skills to represent information, but also on an individual user's cognition, his or her spatial and visual abilities, and prior experience with interpreting map schemata. Visual tasks include scanning the visual scene, detecting patterns, shapes, graphs, edges, discriminating labels, text, color, motion, properties of objects and surfaces (relative size, magnitude), relationships, discriminating 2-D shape from 3-D objects, grouping similar objects and regions, focusing on a spotlight, recognizing landmarks (MacEachren, 1995), relating distances and values, identifying clusters (Koua, 2005), reading and comparing values (Edsall, 2001).

Although some of the visual tasks appear to be similar to interactions with KOS (such as identifying and locating), they are not the same. In visual tasks, *identifying* is associated with the perception of properties of objects encoded on graphical representations. In the context of cartography and geovisualization, *identifying* is related to properties of geospatial locations. *Identifying* in the sense of KOS interactions is associated with documents. Another distinction is that unlike relationships between documents that have to be specified explicitly in metadata records, relationships that become noticeable during visual tasks are not necessarily hard-coded relationships (i.e., such relationships are not explicitly specified in metadata, rather they emerge from documents or their properties when document representations are placed next to each other on a map or some other graphical representation). This distinction suggests that visual tasks may help users reveal many more relationships among documents than it is possible to discover with the tasks specified in bibliographic objectives.

This accumulated evidence about ontological properties in KOS, representations, interactions, sensemaking, and visual tasks suggests that it is time to re-conceptualize the existing map-based visualizations of document collections that are still limited to searching and browsing. Such a re-conceptualization should take full advantage of representations and interactions and should connect them with visual tasks and sensemaking activities about collections.

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Chapter 3: Extending Map-Based Visualizations to Support Visual Tasks: The Role of Ontological Properties[1]

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Abstract

Map-based visualizations of document collections have become popular in recent times. However, most of these visualizations emphasize only geospatial properties of objects, leaving out other ontological properties. In this paper we propose to extend these visualizations to include non-geospatial properties of documents to support users with elementary and synoptic visual tasks. More specifically, additional suitable representations that can enhance the utility of map-based visualizations are discussed. To demonstrate the utility of the proposed solution, we have developed a prototype map-based visualization system using Google Maps (GM) which demonstrates how additional representations can be beneficial.

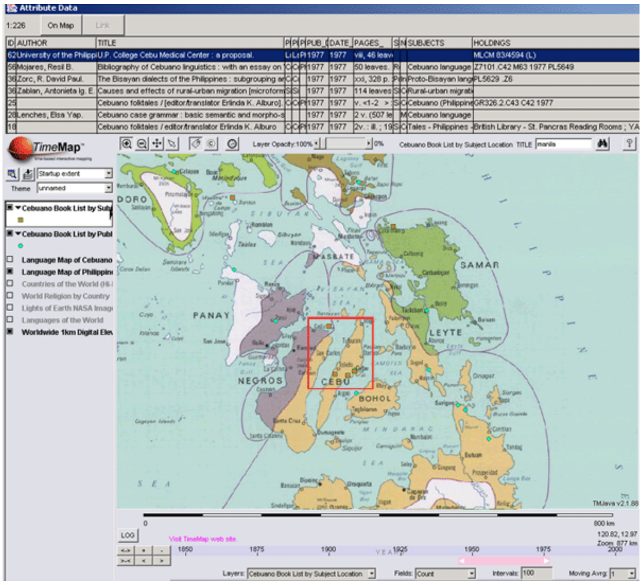
3.1 Introduction

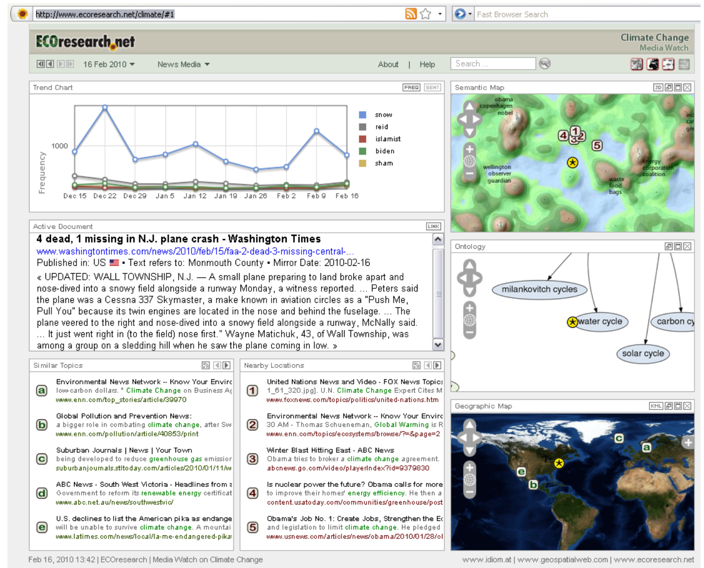
In recent times, visualizing geospatial properties of books and other documents has become increasingly popular. Examples of such visualizations are book rings in Google Earth (Jones, 2008, 29min. 30 sec.), visualizations of geographical references illustrating Google Books Search (http://books.google.com/), Atlas of Fiction (http://www.atlasoffiction.com/), Bible Map (http://www.biblemap.org/), and many others. These visualizations appeal to users due to their rich interaction possibilities (i.e., zooming, panning, flybys) and innovative and interesting ways of presenting and accessing information about documents.

Significant theoretical work has been done for the visualization of documents on digital maps in digital library projects. A project of Electronic Cultural Atlas Initiative (ECAI) used a digital map to facilitate searching a collection of 700 MARC records about, or published in, the Cebuano region of the Philippines (Buckland et al. 2007). Another project, *Going Places in the Catalog: Improved Geographic Access* (Buckland et al. 2007), has experimented with the translation of spatial queries, drawn on a map in various graphical and textual forms, and time/space visualizations of documents using the TimeMap software (Archaeological Computing Laboratory - University of Sydney 2004).

Geovisualization researchers have also been interested in the visualization of documents. Stryker et al. (2008) describe a map-based visualization for tracking infectious disease threats such as Avian Influenza in the media. In their visualization, text extracted from documents can be queried and represented as visual artifacts within a map, timeline, or an extended tag cloud. These linked representations enable the user to progressively filter a collection of documents by interacting with location, time, and theme. A slightly different set of coordinated representations is implemented in the Media Watch on Climate Change visualization (a domain-specific news aggregation portal available at http://www.ecoresearch.net/climate/) (Hubmann-Haidvogel et al. 2009). Representations in this visualization include a synchronized geospatial map, a set of three semantic views (Semantic Map in a form of a spatialization, Ontology View, where concepts are interrelated, and Tag Cloud), and a linear frequency graph of the five most popular keywords. Views represent the different dimensions of the contextualized information spaces, providing the user with multiple perspectives on the latest news media coverage.

Regardless of who develops such visualizations, they have similar designs, mainly consisting of maps, timelines, small legends, and representations of themes and subjects. Such designs are space-, time-, and topic-centred; that is, their primary focus is the visualization of geographic space, time, and sometimes topics or themes. Below we present two examples of map-based visualizations which demonstrate this approach. One is the TimeMap software (see Figure 3.1.a), often used for visualizing library collections. Another is the Climate Change Media Watch, used by geoscientists for interpreting news about climate research. Both visualizations have maps, timelines, and representations of subjects (e.g., the TimeMap has a drop down list of themes; and the Climate Change Media Watch has three views: the Semantic Map, the Ontology View and the geospatial map which alternates with the Tag Cloud).





a) b)

Figure 3. 1 Examples of space-time-and-topic-centric map-based visualizations: a) TimeMap interface (Zerneke et al. 2006); b) Climate Change Media Watch Interface (described in Hubmann-Haidvogel, Scharl, & Weichselbraun, 2009).

The noticeable elements absent in these visualizations are the graphical representations of ontological properties of documents. In terms of library and information science, ontological properties are resource descriptors that describe properties of documents, not information about metadata records, metadata contributors or metadata creators. Ontological properties of documents may include information about title, various kinds of subjects, authorship, explicit relationships among documents, coverage, rights, language, form/genre, illustrative matter, bibliography, time of acquisition, time of publication, classifications, citations, and others. Some of these other properties have been visualized in Envision Digital Library Project (1991-1995) (Fox et al. 1993; Fox et al. 1995; Heath et al. 1995; Nowell 1997) and in FilmFinder (Ahlberg & Shneiderman 1994; Ahlberg et al. 1992) but not map-based visualizations. In map-based visualizations these properties are generally linked to maps in traditional text format, which, as we argue, is not well-suited for a variety of visual tasks that are commonly performed on maps. To improve the architecture of map-based visualizations and facilitate the performance of visual tasks, we propose to integrate additional representations of ontological properties into digital maps.

A variety of representations have been empirically shown to be useful in a number of scientific map-based visualizations (e.g., Liao et al. 2006; Koua 2005; Guo et al. 2005; MacEachren et al. 2003). Additionally, multiple representations have been found to be effective for visualizing geospatial metadata (Ahonen-Rainio 2005). Many of these map-based visualizations are linked to self-organizing maps, parallel coordinate plots, multivariate representations, animations, and reorderable matrices. These representations facilitate both visual tasks with maps and visual exploration of patterns that are otherwise difficult to discover.

In the context of library and information science, the terms *visualization* and *graphical representation* are often used interchangeably, even though in other contexts, visualization implies only a set of graphical representations (i.e., visual artifacts that encode information in a graphical form and make effective use of human visual perception). In this paper, the interchangeable convention will be used, since the primary concern is the discussion and selection of representations that facilitate visual tasks. In general, we consider a visualization to be more than just a set of representations; we are mostly interested in how people interact with representations.

This paper brings together research from a variety of fields, such as information visualization, geovisualization, human-computer interaction, and cognitive science, to address the issue of visualizing non-geospatial properties of documents with map-based visualizations of library collections. It introduces a conceptualization that merges isolated research directions and defines the new research foci in map-based visualization. We not only propose to use additional representations, but also examine how these representations can facilitate visual tasks. To demonstrate the benefits of this conceptualization, a prototypical interactive map-based visualization using GM has been developed.

The remainder of the paper is divided into three parts. In the next section, we review ontological properties of documents (books in particular), current practice of visualizing library collections using maps, and visual tasks that can be performed with these visualizations. In the following section, we describe possible representations of ontological properties of documents using GM. This part explains how individual properties can be encoded using different representations and which tasks can be supported by each representation. In the final section, we conclude the discussion and point to the future research suggested by our conceptualization.

3.2 Background Information

3.2.1 Ontological Properties of Documents and Other Objects

Libraries deal with many physical and abstract objects. These include documents or sets of documents such as bibliographic works or bibliographic families (Svenonius 2000; Smiraglia 2002; IFLA Study Group on the Functional Requirements for Bibliographic Records, 1998), geographic entities, authors, subjects, and sometimes time periods. Documents and bibliographic works are generally the most significant of these objects; the rest are supplementary and traditionally have been used to support the organization of documents. Each of these objects with the exception of bibliographic works, have ontological properties that are captured in knowledge organization systems (KOS). Generally, properties of documents are described in item-level metadata records; properties of placenames are described in gazetteer records or placename authority records; properties of authors are described in authority records; and properties of subjects are described in classifications. Bibliographic works along with their expressions and manifestations are derived from entries in several KOS according to the Functional Requirements for Bibliographic Records (FRBR) that provide guidelines for determining the boundaries of a work (IFLA Study Group on the Functional Requirements for Bibliographic Records 1998). Gazetteers, authority records, and classification schemes are widely known in LIS as KOS (Hill et al. 2002; Zeng 2008). They are characterized by rich content and reside outside the collections of objects. They contribute controlled sets of labels for concepts, authors' names, definitions, and relationships to item-level metadata records. In this paper we extend the notion of KOS to item-level metadata standards such as Machine Readable Cataloguing (MARC). Although MARC is distinct from other content-containing KOS objects such as authority records and gazetteers, which we use to populate the fields in a particular MARC record, it has rich content and is used to organize knowledge similar to other KOS schemes. For this reason, we consider MARC as a special form of a KOS and will refer to all knowledge organization schemes as KOS throughout this paper.

The ontological properties of a book can be categorized as either physical or conceptual. Physical properties refer to the number of pages and the height of the book, descriptions of illustrative matter (presence of illustrations, maps, portraits), bibliographic notes, standard numbers, publication year, place of publication, edition information, and so on. Conceptual properties refer to titles, subjects (including geographic subjects), authors, publication types, call numbers, publication language, and relationships with other documents. According to the final report of the MARC Content Designation Utilization Project that studied commonly populated fields in MARC, the above-mentioned properties are the most frequently described in MARC records out of all published materials (including books, pamphlets, and printed sheet records) (Moen & Miksa 2007). Additionally, a subset of these properties is more or less common to all other metadata standards such as Dublin Core, International Standard Bibliographic Description (see crosswalks among ontological properties in various standards such as Network Development and MARC Standards Office, Library of Congress 2001).

Metadata records reference various other KOS, each of which has its own unique structure. The Library of Congress Classification (LCC), for example, has a hierarchical structure composed of classes and subclasses. Each class has a name and a call number associated with it. The LCSH also has its own structure, which includes subjects, their synonyms, and variant spellings. Its subjects have various relationships to other subjects and are arranged into a hierarchy. Name authority records capture information about authors such as established standardized names, nicknames, pseudonyms, years of life, and references where the information about authors came from. Series and uniform title authority records contain information about any document that has been published under more than one *title*. The best way to describe geospatial properties is by using gazetteers (Hill 2006). Gazetteers are special kinds of KOS which describe properties of geospatial locations such as coordinates, placenames, variant names, and types of places (ibid.). Once placenames are described in gazetteers, they can later be referenced in metadata records.

Ontological properties of documents have many usages. They are used for organizing and sharing knowledge, retrieving information, judging relevance, collocating bibliographic works, and comparing documents. KOS that record ontological properties set standard criteria according to which items can be compared and judged. Some conceptual properties are more important than physical ones for the retrieval and organization of knowledge, and users rarely name physical properties as important criteria in relevance judgements (Barry 1994; Savolainen & Kari 2006; Tombros et al. 2005; Xu & Chen 2006). These lesser-used physical properties, however, may provide information as to the probable structure and organization of key elements within a text. For instance, when readers pick up a book, they are afforded numerous aesthetic cues such as its size, age, condition, and number of pages, which can be indicators for effort involved in reading it, relevance, and previous usage rates, respectively (Dillon 2004; Reuter 2007). Often when one is searching for pictorial works, art albums, or atlases, the size of a book might become a valuable piece of information in determining its relevance. Determining and comparing book sizes in current map-based visualizations, however, is not a task which average library users generally know how to accomplish. But representing this information graphically can aid users in performing such tasks. For this reason, we emphasize that map-based visualizations should be KOS-fit. That is, they should represent more than just geospatial, temporal, and topical properties; rather they should represent other properties in order to provide users with the right information to perform quantitative and qualitative comparisons, as well as other visual tasks.

3.2.2 Representations

Map-based visualizations are hierarchical structures comprised of a variety of lower-level representations such as symbols, icons, text, images, diagrams, plots, tables, and even maps. Each type of lower-level representation has utility depending on the context in which it is used. For instance, in science education, diagrams can facilitate understanding of laws and problems (Chen 1996; Cheng 1992); in health sciences, symbols may help with symptom elicitation (Moriyama et al. 1994); and, in literacy education, symbols may provide cues to word meanings (Sheehy 2002; Fossett & Mirenda 2006).

Map-based visualizations often use base maps and other representations such as symbols, icons, timelines, labels, and subject representations. A base map is the ground layer upon which other layers of data are displayed. Examples of base maps are planimetric maps, topographic maps, and satellite views (Hill 2006). In map-based visualizations of KOS, base maps can be used to represent the structure of classifications (the LCC in particular) (Buchel 2006). For example, linguistic maps can be used as base maps for language and literature classes in the LCC, and historical maps for some historical classes.

Symbols and icons come in many different forms. Examples include markers, balloons (as used by GM), prisms (as used by Platial.com), graduated circles (as used by Flickr.com), 3D spatial histograms (Ancona et al. 2002), iconic stacks, differently-shaped coloured blocks (Ahonen-Rainio & Kraak 2005), and many others. When used in the context of maps, symbols and icons can make desired information perceptually salient. They can also make the relations between geospatial objects more readily apparent, which can facilitate higher-order knowledge-oriented activities such as problem solving, decision making, and hypothesis generation. When icons or symbols are viewed together, they should form a cohesive picture so that overall patterns in the multivariate information space can be discerned (Harris 1999; Dorling 1991). In other words, multiple icons should allow users to exploit the capacity to sense and discriminate the texture of a complex image (Pickett & Grinstein 1988). The purpose of icons at this level is to facilitate overall comparisons of objects and the identification of trends and unusual patterns in information (Harris 1999).

Most icons and symbols used in map-based visualizations of documents show counts, density, or simply serve as landmarks for objects. The purpose of icons such as Chernoff faces (Chernoff 1973), star glyphs, whisker plots (Ware 2004), and multidimensional icons (Spence 2007) is to encode rich ontological properties of documents. Such icons, when viewed together, can create interesting perceptual effects. For example, Chernoff faces may merge to form crowds, where one can easily compare faces to look for family resemblances or the mood of the crowd. Icons in the form of houses can be perceived as towns, allowing particular suburbs, estates, and streets to be identified (Harris 1999; Dorling 1991). The limitation of multidimensional icons, however, is their low dimensionality. Theoretically, the highest number of variables that Chernoff faces can encode is around 36 (Flury & Riedwyl 1981), but in reality, icons are hard to classify or associate when there are too many dimensions. Moreover, it has been found that not all facial features are equally distinguishable. De Soete and De Corte (1985) have demonstrated, for example, that only mouth curvature, eye size, and eyebrow density variables are the most salient. Ware (2004) recommends that star glyphs and whisker plots should use only a very small number of orientations (possibly 3), in order to facilitate rapid classification and association of glyphs. In addition, Chernoff faces may arouse emotions among subjects and may lead to confusing interpretations (Ahonen-Rainio 2005).

Labels should be an integral part of any graphical representation. According to Tufte (2001, 180), "Viewers need help that words can provide. It is nearly always helpful ... to label outliers and interesting points." Additionally, label sizes and colours may facilitate the grouping of semantically-related labels, and may guide one's attention and increase the possibility of learning something from the graphical representation (Götzelmann et al. 2005a). For users that are not familiar with the geography of the visualized region, map labels may aid in the exploration of relative locations of cities using cardinal directions, and relations between cities in terms of distances which are missing in alphabetical arrangements in the LCC.

Tufte (2001) also recommends placing labels directly on the graphic itself without the use of legends, because "words and pictures belong together, genuinely together" (Tufte 1990, 116). Legends may prevent users from seeing each part and its label together. Other detailed aesthetic and legibility requirements for positioning geographic labels on maps are described in (Imhof 1975). To summarize, geographic labels should be legible, be easily associated with features they describe, reflect the hierarchy of features by the use of different font sizes, and not be densely clustered, evenly dispersed, or overlap other map contents. The hierarchy of cities is traditionally derived from population sizes. Cities with larger populations have larger labels, while cities with lower populations have smaller labels.

Timelines have attracted much interest from researchers in the areas of digital libraries and geovisualization over the past two decades. While digital library researchers have investigated how to integrate temporal gazetteers (also known as time directories) with map-based visualizations (Zerneke et al. 2006), geovisualization researchers have been working on the graphical representation of time in geographic information systems (Edsall 2001; Li & Kraak 2008; Peuquet 2002). The proposed representations can encode time in a linear, cyclical, combination of the two, or even static manner. In the age of print maps, for example, time was typically encoded using labels (Vasiliev 1997). For the visualization of documents, both linear time encodings and text labels are suitable, although the former is preferred. Together, as the linked maps and other displays change, KOS and graphical timelines allow zooming and scrolling while the linked maps and other displays change to reflect the state of information at a moment in time.

Subject and theme representations are also part of map-based visualizations. Information visualization researchers have used a variety of techniques for visualizing subjects. For example, subjects can be represented as a Kohonen Map (Kohonen 1995), Tree Map (Shneiderman 1992), Topic Map (Weerdt et al. 2007; Le Grand & Soto 2002), Flickr-Style Tag Cloud (Bausch & Bumgardner 2006), Cartogram (Keim et al. 2003), Fisheye View (Furnas 1986), Hyperbolic Tree (Lamping et al. 1995), and others. These representations have the aesthetic appearance and proper balance between visualization models and underlying data, as strongly connected nodes appear close to each other, and weakly connected nodes appear far apart (Chen C. 2004). The scalability issue, however, is one of the serious drawbacks of these representations. As the size and density of data increases, most of these representations do not scale well.

Other subject representations such as spatialization techniques have been introduced by cartographers. An example of a spatialization is ThemeScape (Wise et al. 1995). Spatializations use spatial metaphors such as distance-similarity, direction, scale, arrangement, regionalization, and landscape (Montello et al. 2003; Fabrikant et al. 2004). These metaphors are built on analogy with the real world and allow users to intuitively explore the space (Börner et al. 2003). Spatializations typically employ dimension reduction techniques and layout algorithms to project similarity in subjects onto distance, such that semantically-similar subjects are placed closer to one another (Börner et al. 2003).

Map-based visualizations cannot be complete without interactive legends. With print maps legends typically contain a heading and labels, legend boxes, or symbols to depict numerical values or nominal classes, class units, and explanatory text (Sieber et al. 2005). Static legends are often criticized for impeding visual tasks, because users have “to dart back and forth between textual material and the graphic” (Tufte 2001, 180). On the other hand, digital maps, due to their interactive nature, do not have this shortcoming, as they are mobile and dynamic. Digital legends are no longer used solely for decoding purposes. They can be used for modifying the appearance of the map and the classification of the data, for performing information retrieval (querying the thematic layers), and for filtering the results (data extraction and data suppression) (Sieber et al. 2005). As to the design of legends, surprisingly it is not easy to find any clear guidelines or recommendations for their design, except for the framework for the design of self-adaptable legends for digital atlases by Sieber and colleagues (2005).

Ontological properties of documents in metadata are traditionally linked to maps either as tabulated text or tables (see an example in Figure 3.2). When information elements are encoded in a table, exact details are more easily extracted because users know which field to attend to (Newton 1994), and juxtaposed cells can highlight differences (Winn 1987). Tables are usually more effective than graphical encodings for small datasets (Tufte 2001). As tables get larger, however, search is hindered by a large number of distractors with multiple features. For this reason, if a precise match is found in a large table, the user has no way to know whether or not it is the best match (Spence 2007).

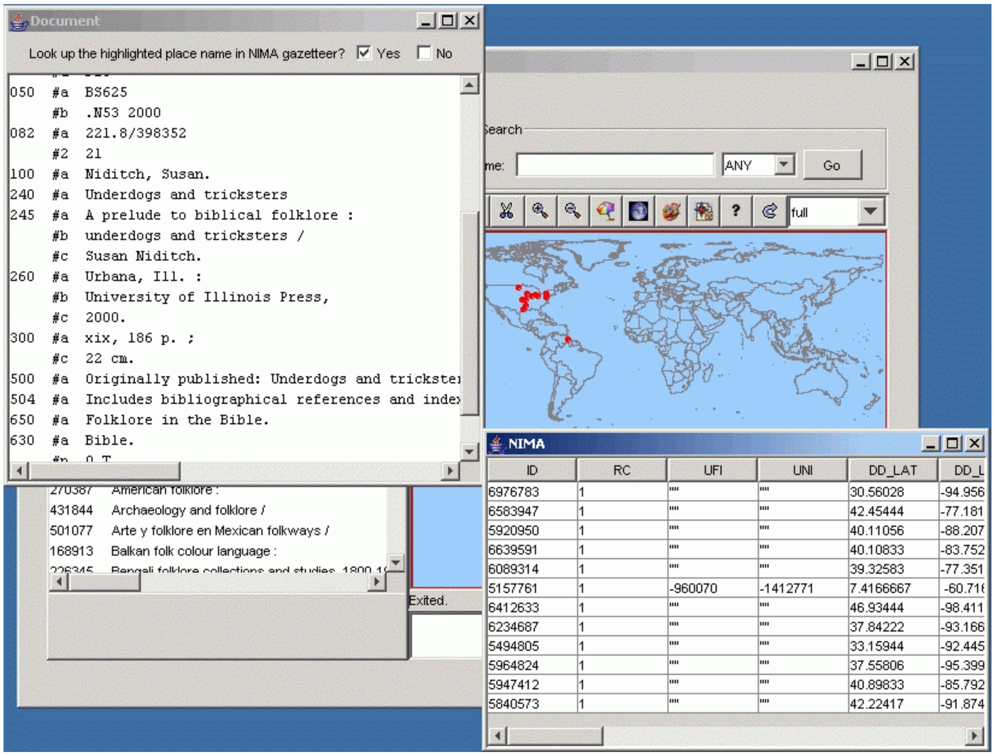


Figure 3. 2 A map-based visualization with links to metadata and gazetteer records which are represented either as tabulated text or a table (Electronic Cultural Atlas Initiative 2004).

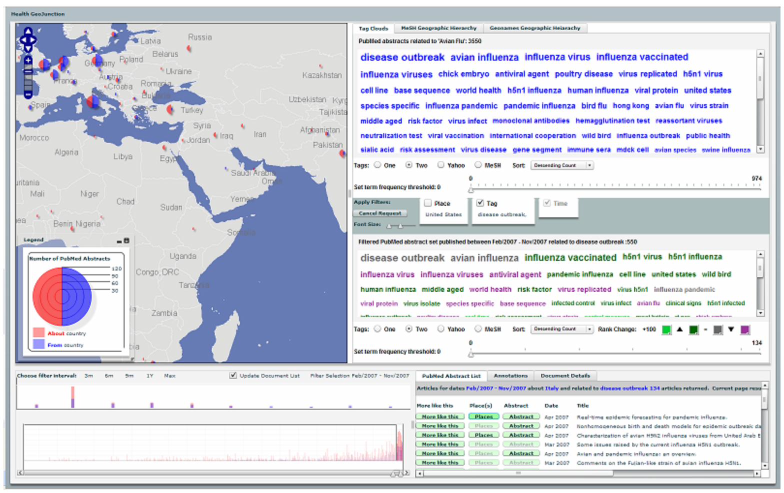
Tables and tabulated text make it easier for users to "visually parse" the metadata fields, but they do not facilitate reasoning about relative locations of documents and relationships among them. For instance, tabulated text may describe concrete physical and relative locations of documents, but without encoding the locations graphically, inferences can be difficult to make (Brown & Dowling 1998). Veerasamy (1997) suggests another problem with such textual encodings: metadata records can only be viewed individually instead of as a set, which does not allow for distinguishing and grouping documents based on their commonalities and idiosyncrasies. Additionally, tables often list only key ontological properties (e.g., title, subject, the year of publication, and call number for documents), thus preventing users from comparing physical properties of documents. As a result of these shortcomings, users often engage in shallow processing of the information space while extracting elements from tables (Newton 1994; Vonk & Noordman 1990).

To facilitate the comprehension of ontological properties, additional graphical representations can be used. Modern digital maps such as GM and Google Earth allow symbols and icons to be linked to other representations (e.g., other maps, images, plots, charts, self-organizing maps, diagrams, timelines, and legends). In general, representations can be linked by either one of three linking types: replacing, overlaying, and repeating (Wilhelm 2008). Depending on the context in which they are used, different linking techniques can either enhance or impede visual exploration of representations (Wilhelm 2008; Plaisant 2005; Sedig et al. 2005). With the first type of linking, replacing, old information is typically lost and gets replaced by new information. The shortcoming of such linking is that relevant previous states must be held in one's memory if they are to be integrated with new knowledge (Wilhelm 2008). Replacing is used in cartographic space-time animations, which are composed of a series of image frames, where each image appears later in time than the previous (Bétrancourt & Tversky 2000). The downside of these animations is that they may cause change-blindness, since users have to keep track of multiple events occurring simultaneously that require them to split their visual attention (Lowe 1999; 2003; Fabrikant et al. 2008). For example, Rensink and colleagues (1997) have demonstrated that users have great difficulty noticing even large abrupt changes between two successive scenes in an animation, when blank images are shown between scenes. This can be overcome, however, when changes in representations are caused by user interaction (Sedig, et al. 2005; Wilhelm 2008).

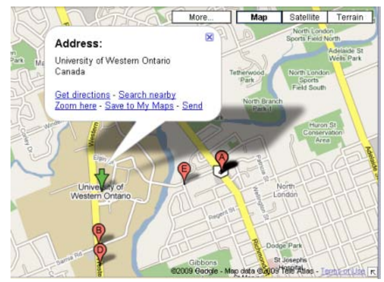
In the second type of linking, overlaying, the new information is placed on top of the original representation. Typically, map overlays are opaque, conform to the scale of the original map, and are georegistered to the geographic location on the main map. Figure 3.3 shows a map where overlaying is used. In this example the map is overlaid on an aerial image. Such overlays help users to compare the accuracy of representations, or to develop a composite representation of a location, combining both the original representation and the overlay. Identical scales in linked maps and georegistration provide a common framework for comparing the linked layers. Overlaying facilitates the comparison of linked representations, since the differences between the two are so readily apparent. Examples of where overlaying has been used are in map and aerial imagery collections (e.g., as described in Forbes & Janée 2007, and in the David Rumsey Map Collection at http://www.davidrumsey.com/).

Figure 3. 3 A map overlay. Such overlays help users to compare the accuracy of representations, or to develop a composite representation of a location, combining both the original representation and the overlay.
Source: http://naturalsciences.org/microsites/education/treks/yellowstone/images/places/index.html

In the third type of linking, repetition, the displays are juxtaposed and different representations of the same data are available. This is a preferred type of linking for many map-based visualizations. Such visualizations place juxtaposed representations on the screen, and their changes are synchronized (see an example in Figure 3.4.a). The advantage of this type of linking is that it provides a rather comprehensive picture of the data; the user has a complete overview of every representation and can clearly observe the impact of changes in one representation on another. Problems with this type of linking include lack of screen space and an often unintuitive interface. Users frequently need help to understand the interface, especially when using an unfamiliar application (Andrienko N. et al. 2002). To overcome the complexity of juxtaposed representations, Plaisant (2005) proposes to use the metaphor of sticky notes overlaid on top of the linked views. This is meant to help locate the main widgets, demonstrate their manipulation, and explain the resulting actions.



a)



b)

Figure 3. Examples of linking by repetition: a) repetition in juxtaposed layers and frames; b) repetition via information windows in GM.

GM use a different solution for overcoming complexity. They allow linking additional graphical representations via information windows which can be opened or closed on request (as shown in Figure 4.b). This is similar to linking by repetition, but not in its pure form, since the linked view does not remain on the screen all the time. The drawback of such linking is that it prevents comparisons between multiple linked views.

3.2.3 Visual Tasks

Traditionally, textual representations of ontological properties are used to support information retrieval tasks, such as finding, identifying, selecting entities, and acquiring or obtaining access to the entities (Svenonius 2000). However, retrieval tasks are not enough. Users should also be able to engage in visual tasks. These include scanning the visual scene; detecting patterns, shapes, graphs, and edges; discriminating labels, text, color, motion, properties of objects and surfaces (relative size, magnitude), and relationships; discriminating 2-D shapes from 3-D objects; grouping similar objects and regions; focusing on a spotlight; recognizing landmarks (MacEachren 1995); relating distances (semantic similarity or geospatial relevance) and values; identifying clusters (Koua 2005); and reading and comparing values (Edsall 2001). The most basic visual tasks performed while reading maps are identifying, locating, comparing, and associating (Andrienko G. et al. 2005). While identifying, users search for thematic characteristics of objects; while locating, users search for positions of objects in time and space; while comparing, users establish qualitative and quantitative relationships; while associating, users relate attribute values or spatial patterns (Andrienko G. et al. 2005). While information retrieval tasks can be delegated to a computer, visual tasks can only be performed by users. The efficacy of supporting visual tasks depends not only on the designer's skills to represent information, but also on individual user's cognitive, spatial, and visual abilities.

Visual tasks can be further divided into elementary and synoptic exploratory tasks (Andrienko N. & Andrienko G. 2006). Elementary tasks refer to identifying individual elements of the reference set. For example, finding the value of an attribute corresponding to a certain specified reference such as *how many books a library has about a particular city* or *how the books in a collection are distributed geographically.* Synoptic tasks involve the identification of the whole reference set or its subsets. In such tasks, sets of references are considered in the entirety of their characteristics (which include behaviours and relations between reference sets or between behaviours). Here, behaviours refer to distributions, variations, and trends. An example of a synoptic task would be determining the variation of document counts over a whole county or country. Among synoptic tasks, the most challenging are tasks of finding connections between phenomena (e.g., cause-and-effect relationships or finding the principles of the internal organization, functioning, or development) (Andrienko N. & Andrienko G. 2006).

The possibility of map-based visualizations to support such a variety of visual tasks increases their utility in comparison to text-based library catalogs. Whereas well-designed map-based visualizations can reveal implicit relationships among library collections, traditional textual representations can only help with identifying and locating items, associating documents with hard-coded relationships, and navigating between geographic places by means of broader and narrower relationships. Maps, on the other hand, allow users to see locations in time and space, learn about nearby cities, distances between cities, directions, changes over time, and so on. Despite these additional advantages, maps do not facilitate visual tasks for comparing and associating documents. In order to design visualizations that support visual tasks, maps must be augmented with additional graphical representations that allow users to identify, compare, associate, and locate documents visually. This will allow users to perform not only elementary tasks of finding items, but also synoptic tasks which allow them to see trends and patterns in publication and acquisition data. This is important for scalable map-based visualizations with hundreds and thousands of metadata records linked to each city.

3.3 Prototype Map-Based Visualization System

In this section we describe our selected testbed document collection, our prototype system (Section 3.3.1), and our design of graphical representations that encode ontological properties of documents (Section 3.3.2).

3.3.1 Selected Document Collection

For the purposes of this research, we have selected an experimental collection of documents. Our collection is comprised of 349 records from the Library of Congress Catalogue. We used the LCC structure to guide our selection of records to visualize, since geographical and chronological arrangements in the LCC are framed in accordance with the needs of each subject field. The LCC has been "praised for the freedom allowed in each schedule for development according to its subject field's own intrinsic structure" (Angell 1964). This intrinsic structure can facilitate the development of interesting map-based visualizations for each subject field, which can hardly be derived from simpler structures. Each individual geographic arrangement along with other related classes in the LCC can be characterized as a mini-ontology of a certain theme. Some of these mini-ontologies include georeferences (i.e., geographic names), temporal references, and other elements. These elements can be grouped together in map-based visualizations. An example of a geographic mini-ontology in the LCC is the "Local History and Description" classes. Ranges of geographical references about the "Local History and Description" classes are dispersed throughout the schedules D and F of the LCC. They list various countries, cities, and other placenames, to which resources about the "Local History and Description" of those places are linked. Some of these ranges are presented in Table 1:

Country	LCC schedules
Afghanistan	DS374-375
Austria	DB101-879
Canada	F1001-1145.2
China	DS781-796
Finland	DL1170-1180
India	DS483-486
Italy	DG600-975
Japan	DS894-897
Korea	DS936-937
Portugal	DP702-802
Russia	DK511-651
Spain	DP285-402
Switzerland	DQ301-857
Ukraine	DK508
USA	F10-975

Table 3. 1 LCC Classes About Local History and Description (Library of Congress, n.d.)

This list is far from complete, as there are many more ranges like these. Some of these ranges have more georeferences than others. Among georeferences within the specified ranges, one can identify geographic concepts of various scales (ranging from countries, regions, and cities to small geographic locations).

Documents in the "Local History and Description" mini-ontologies share many common features. First, they have similarities in bibliographic descriptions, as they have similar subjects and forms/genres, are written in the same languages, are published in close locations, have similar call numbers, and are placed on the shelves close to each other. Second, many of these items contain illustrative matter (illustrations, maps, portraits, and so on), because they relate the history of geographic places. Third, some of the items have large formats, which can be of great interest to users (e.g., oversized pictorial works). Fourth, in terms of forms, cataloguers place travel guides, encyclopedias, directories, guidebooks, pictorial works, tour guides, and other similar items in these sections. Fifth, they have no temporal features (i.e., items within these ranges are not arranged according to time periods).

All records in our testbed collection have call numbers starting from DK508. Class DK508 is an example of the mini-ontology described above. All records within this mini-ontology have the same subject — "Local History and Description" of Ukraine. All documents within this class are about Ukraine, including regions and cities. For example, subclasses DK508.922-DK508.939 are assigned to documents about Kiev, DK508.95.L86 to documents about L'viv, and DK508.95.O33 to documents about Odessa. There are a few exceptions where a subclass includes documents about more than one geographic location, but these are rare. An item about L'viv (title: Lwów, przewodnik / Ryszard Chanas, Janusz Czerwiński), for instance, has a call number starting with DK508.924, which belongs to the range of call numbers assigned to Kiev. This item was eliminated from the subset during the uploading in the research prototype. Among downloaded records there are the entire subsets of records for 32 Ukrainian cities (among which the largest cities are Kiev, Odessa, L'viv, and Kharkiv). The numbers of MARC records linked to each city subclass in DK508 range from a few records to almost a hundred.

From each MARC record only the key ontological properties were selected. They are physical descriptions (illustrations, maps, height of the book, number of pages in the book, year of publication, place of publication – all of these attributes are recorded in MARC 300), languages (field 041), types of publication (serial or monograph, field 006), bibliographic notes (MARC 504), subjects (fields 650 and 651), titles (field 245), call numbers (field 050), and acquisition numbers (MARC 010). Other properties, such as standard numbers, geographic area codes, uniform titles, variant titles, edition statements, publication and distribution information, series statements, note fields, were considered beyond the scope of this research, because of their low occurrence rates in the testbed collection. All records were downloaded into a MySQL database.

Georeferences in the LCC are indirect; that is, for describing locations on a map, each placename requires a mathematical representation in the form of geospatial coordinates. As was mentioned in Section 2.1, the best practice to describe geospatial properties is by using gazetteers. In our prototype, we used a custom-built gazetteer which includes footprint information (latitude and longitude), names (main and variant), and feature types represented by population sizes.

As records were downloaded, the raw data was very carefully inspected and potential problems with the representation of certain fields were identified. For example, book pagination usually has mixed notation (e.g., 81 p., [8] p. of plates; xviii, 204 p., [1] folded leaf of plates). Such notation is difficult to summarize computationally. For now, only values recorded as Arabic numerals were used in the visualization. More experimental work is required to decide what to do with the remaining notations.

Another problem with the testbed dataset is missing values, typical of many datasets. In book pagination, missing values transpire more often than in the other fields. Instead of pagination, 300 |a, a field may carry information about the number of volumes. The following are the examples of such problematic records, with the field *italicized*:

|a *v. <1>* : **|b** ill. ; **|c** 17 cm. (DK508.935 **|b** .V68 2002)

|a *v. <1-6>* : **|b** ill., maps ; **|c** 17 cm. (DK508.935 **|b** .K68 2002)

|a *2 v.* : **|b** ill. (some col.) ; **|c** 20 cm. (DK508.934.K67 A3 1998)

|a *v. <1-2 >* : **|c** 20 cm. (DK508.933 .K96 1997)

In this paper, we do not address the issue of missing values, as a total of six problematic records with missing values are simply omitted from the visualization. Our omission is justified, as missing values in visualizations are not uncommon. For instance, Ahonen-Rainio (2005) reported that she had missing values in geospatial metadata and had to assign some special codes to the problematic items to make them visible on the display. This helped the users know that the records existed, but that their fields were missing. Some researchers suggest that allowing users to know which values are missing is as important as allowing them to know which ones exist (Tang et al. 2003).

The prototype collection does not include serial records, since their ontological properties are significantly different from the ontological properties of books. To test the visualization design of serials, a larger dataset of serials would be required. The number of serials in our collection was only 2; therefore they were excluded. We also did not include any documents about regions and countries, since their visualizations might require different base maps.

Lastly, when selecting records for the testbed collection, we noticed that some cities included in the LCC no longer exist. Examples include the following names of the cities or locations of ancient fortresses: Chufut Kale (Çufut Qale), Eski-Kermen, Feodosiia Kaffa, and Chersonese. Some of these placenames are names of the cities that existed on the territories of modern cities. For example, the modern town of Feodosiia occupies the sites of ancient cities of Theodosia (which existed between the 6th century B.C. and the 4th century A.D.) and Kaffa (which existed between the 13^{th} to 18^{th} century). It was named Feodosiya only in 1802 (Feodosiya 2007). This is an example where cities temporarily overlap.

To visualize ontological properties of documents, our prototype system uses GM as the visualization platform. All representations and interactions described in this paper are developed with the GM API, PHP, Ajax, and Fusion Charts (http://www.fusioncharts.com/). Although ideas and principles outlined in this paper could be implemented using other geographic information systems, we chose GM because they already have many base layers as well as built-in linking and customization capabilities.

3.3.2 Representations of Ontological Properties

In this section we review additional representations, how they can be linked, what visual tasks they can support, and what ontological properties they can encode. In particular, subsection 3.2.1 describes how to add missing labels for placenames, why they are necessary, and what visual tasks these labels can support in map-based visualizations. Subsection 3.2.2 discusses the design and role of symbols. The design of timelines and the visual tasks they support is presented in subsection 3.2.3. Subsections 3.2.4-3.2.5 explain the possible design and application of digital legends. Finally, the concluding subsection 3.2.6 explores the utility of additional graphical representations in map-based visualizations.

3.3.2.1 Placename Labels

The most important ontological property of documents for map-based visualizations is georeferences. Because GM has a built-in gazetteer and has labels for the majority of placenames, many developers of map-based visualizations approach the design of maps with the assumption that displaying labels for georeferences is not necessary. Although this is true, GM is composed of 18 map layers with various scales and therefore different sets of labels. Due to variations in scales, some layers have names of the cities, while others do not. On some layers, cities are encoded as dots, and on others as small polygons. While designing map-based visualizations, developers choose the most appropriate layers. For instance, layers suitable for the representation of cities of various countries and regions are usually layers 5-10 with GM. On these layers, countries and city locations can be viewed at the proper scale, and users do not have to pan maps in order to view all cities on one map. But many of these layers lack all placename labels, because the size of the location is not big enough to be represented on all map scales. Thus, when mapping cities of Ukraine on layer #7 (which is the most suitable for the visualization of cities in Ukraine), only 17 out of 32 cities that have to be represented have labels. Cities with populations smaller than 500,000 people are not shown on this map layer.

Thus, in order to represent cities with populations smaller than 500,000 people, we could use the following typology:

Cities of less than 10,000

Cities of 10,000 to 100,000

Cities of 100,000 to 200,000

Cities of 200,000 to 500,000

The names of larger cities can be encoded using a larger font than the names of smaller cities. See Figure 3.5 for demonstration of how this approach works on GM, where added placename labels are circled in red.

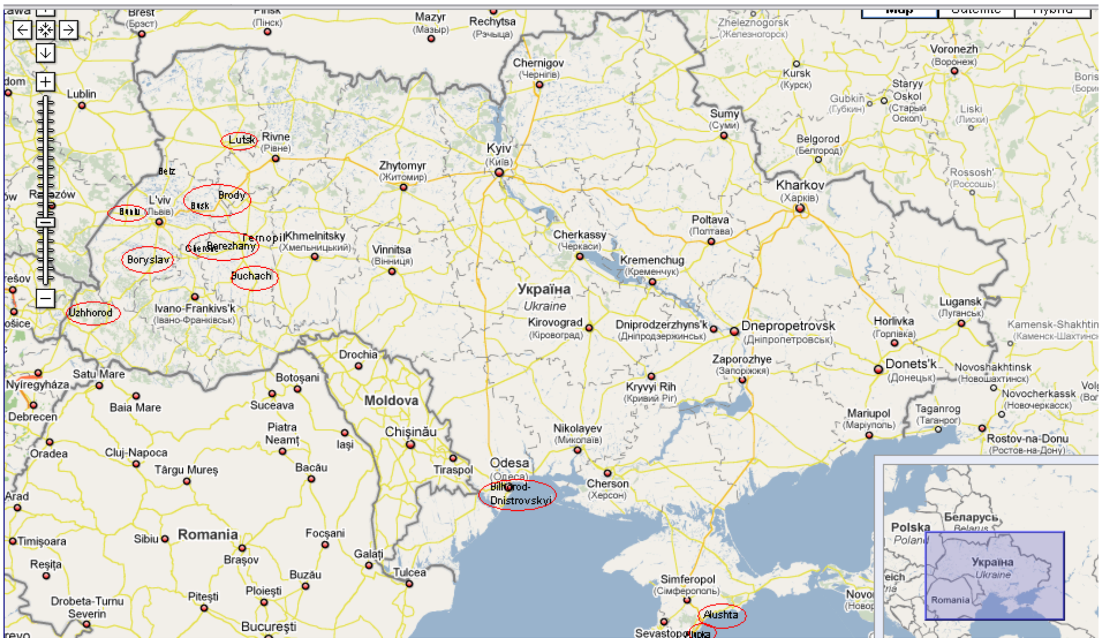
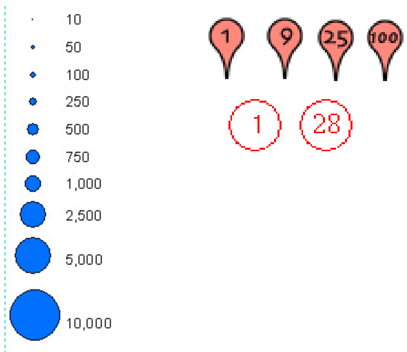


Figure 3. 4 A map with added placename labels.

To provide users with clues about non-existing cities, the labels for such cities may either be shown in a different colour (e.g., red or grey), or visualized with the help of a timeline. In the case of "overlapping" cities, developers could also use sunflower symbols for locations of the cities (e.g., ⅄ + ✶). A sunflower symbol is a dot with short, radiating lines called petals. The number of overlapping cities can be represented by the number of petals (Cleveland & McGill 1984; Harris 2007).

3.3.2.2 Symbols in Map-Based Visualizations

To represent documents, designers traditionally use symbols and icons. Symbols and icons may be neutral (e.g., simple markers), or reveal either the quantity (density) or the semantics of linked objects (i.e., their ontological properties). Examples of quantitative symbols and icons include graduated symbols, or icons with numbers denoting quantities or densities. Quantitative symbols may show counts, averages, sums, mins, maxs, medians, or orders.



a) b)

Figure 3. 5 Examples of quantitative symbols: a) graduated symbols; b) icons with numbers.

At first, it might appear that quantitative values are not relevant to ontological properties of documents that are mainly categorical. Categorical properties, however, can be transformed into counts by mapping the nominal values to numbers (i.e., assigning order and spacing to the nominal values) by means of statistical operations (such as count, average, sum, min, max, median), sorting, or filtering (in order to display only interesting ranges of data) (Rosario et al. 2003). For example, in map-based visualizations, graduated symbols and icons with counts may show quantities of items retrieved for each city (see Figure 3.7). The advantage of markers with actual counts over graduated symbols is that actual counts can support quantitative comparisons in datasets where items are not equally distributed. For example, one of the methods used in the design of graduated symbols is the division by quartiles, where the first 25% of datapoints are shown with the smallest symbol, the next 25% with a larger symbol, and so on (Slocum, et al. 2005). For instance, let us assume that in our collection items 1-10 constitute the first quartile. This means that no matter whether the city has 1 or 2 or 3 or 7 matching items, all of them will be shown as one symbol. This example demonstrates that graduated symbols do not allow users to differentiate between the quantities within the quartile ranges, whereas actual counts can easily do so.

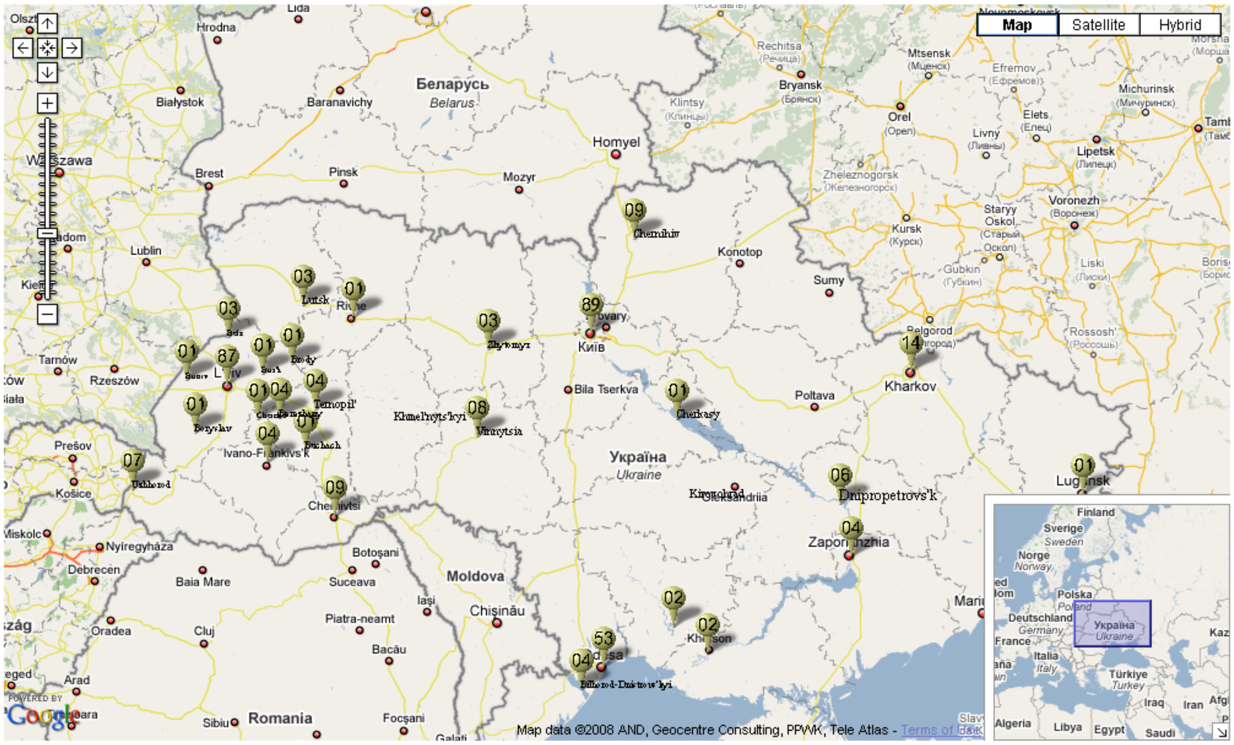


Figure 3. 6 Quantitative symbols on Google Maps.

Quantitative symbols support elementary visual tasks (e.g, locating cities and identifying quantities of items associated with each city), including quantitative comparisons of collections. For example, on the map in Figure 3.7 we can identify the cities with the highest densities (Kyyiv-89, L'viv-87, and Odessa-53), the ones with the lowest densities (Lugansk, Rivne, Boryslav, Brody, Cherche, Buchach, Nikolaev have only one item each), and the ones without any collections. Moreover, symbols become visible after a brief exposure which lasts typically from 30 to 300 milliseconds and is accomplished during preattentive processing (Ware 2004; Spence 2007). The advantage of using symbols that exploit such processing is that it does not require conscious attention and does not overload working memory.

Text labels combined with quantitative symbols may assist users in quantitave comparisons of collections. Counts of objects make it easy to determine which collections are larger and which are smaller, and scaled placename labels facilitate making comparisons among the cities. Logically, the density of collections is higher for well-known, large cities, and lower for small- or medium-sized cities. Any deviations from this may indicate errors, gaps, or other unusual situations.

Multidimensional or semantically-rich icons can encode different ontological properties of documents. Examples of such icons include Chernoff Faces (Chernoff 1973), Star Icons (Ward 1994), and fourfold/twofold displays (Friendly 2000; Stryker et al. 2008). Unfortunately, we were not able to encode ontological properties of datasets for each city. The problem with radar plots, Chernoff faces, and fourfold/twofold displays is that they are only effective for the representation of datasets with high-volume counts. They can hardly be useful for cities with scarce collections such as the one we had selected. We were able to generate multidimensional icons only for 4 cities, since other cities (28 out of 32 cities) have collections less than 20 items.

3.3.2.3 Timelines

Timelines can be used for displaying and tracking events, objects, and activities (Kapler & Wright 2004). Many map-based visualizations of documents typically display only a single dimension of time, most often temporal aboutness (i.e., *the time period of the document* as in ECAI TimeMap). KOS, however, have many other temporal aspects that can be displayed and tracked on timelines, such as publication years, acquisition years, and authors' lifelines. The provision of such timelines can aid users in performing elementary visual tasks involving questions such as:

What was the first book acquired by this collection?

Which books were acquired in 2007?

Books about what cities were written by the authors who lived between 1920-1930?

How recent are the library collections?

What books were written by contemporary authors?

When were most of the books published?

To visualize several temporal aspects, designers in information visualization often use hierarchical timelines (André et al. 2007). Hierarchical timelines can include several linked timesliders, each of which has a time scale and control handles that allow setting a selected range on the time scale (see Figure 3.8 below). To facilitate elementary visual tasks, timelines often include histograms or line plots showing counts of items associated with each time period. Histograms allow users to identify years or time periods with the highest density of activities, events or objects. To ease the quantitative comparisons between different timelines, all timesliders should use identical time scales.

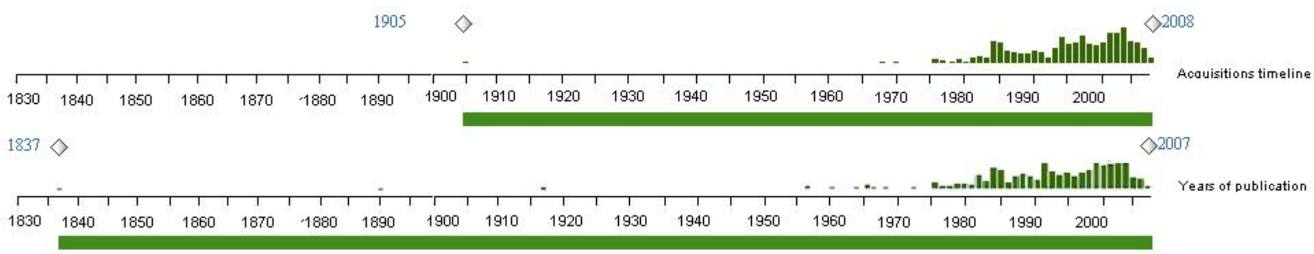


Figure 3. 7 Hierarchical timelines. These timelines represent acquisition and publication years.

Besides elementary visual tasks, hierarchical timelines can allow users to perform an array of visual synoptic tasks, which are not possible with simpler visualizations. Due to the specifics of our prototype collection, however, we did not have enough data for the visualization of all temporal aspects (i.e., temporal aboutness, acquisition timelines, publication timeline, and authors' lifelines). We were able to visualize only acquisition and publication years. But even these two timelines are sufficient to explain and demonstrate the richness of visual synoptic tasks that can be supported when multiple timelines are used and/or linked together. Synoptic tasks are not simply about identifying objects and reading their values; they are more about the comparison of behaviours (Andrienko N. & Andrienko G. 2006). For example, synoptic tasks with acquisition and publication timelines allow users to assess acquisition and publication trends over certain time periods. More specifically, users can answer to the following types of questions:

Which books, published during the Soviet Period, were acquired after 1991?

When were the books acquired in 2004 published?

What is the time-lapse between publication and acquisition of a set of books?

3.3.2.4 Legends

Digital legends are commonly linked to maps either in separate frames or layers. They are linked through repetition and are synchronized with the map so that any change in the legend causes changes in the map, and vice versa. The appearance of digital legends is not always static; rather, they can be self-adaptable (Sieber et al. 2005). Such legends adapt their shape and content to various conditions (e.g., to scaling and repositioning of various layer set-ups). Additionally, adaptive legends can adjust their content to include only symbol categories that actually appear on the map. In this case, the legend may update dynamically according to navigation.

Legends in current map-based visualizations of documents sometimes afford switching between different base maps (e.g., a linguistic map, a physical map, or a religious map), filtering by country or city, and selecting keywords, subjects, or topics. The results of the analysis of ontological properties in our prototype collection suggest that such legends have limited capabilities for interaction with ontological properties of documents. For example, besides subjects and keywords, documents can have information about forms/genres, languages, formats, illustrations, maps, and bibliographic notes.

In our prototype, the legend (see Figure 3.9) displays the most frequently occurring ontological properties: *forms* recorded in form subdivisions (e.g., biographies, dictionaries and encyclopaedias, gazetteers, guidebooks, pictorial works, tours); *frequently used subjects*; and *physical attributes* (e.g., illustrations, maps, portraits, bibliographic notes). The legend may also include other properties such as *categories of placenames* (e.g., extinct and modern, or population sizes) and *languages*.

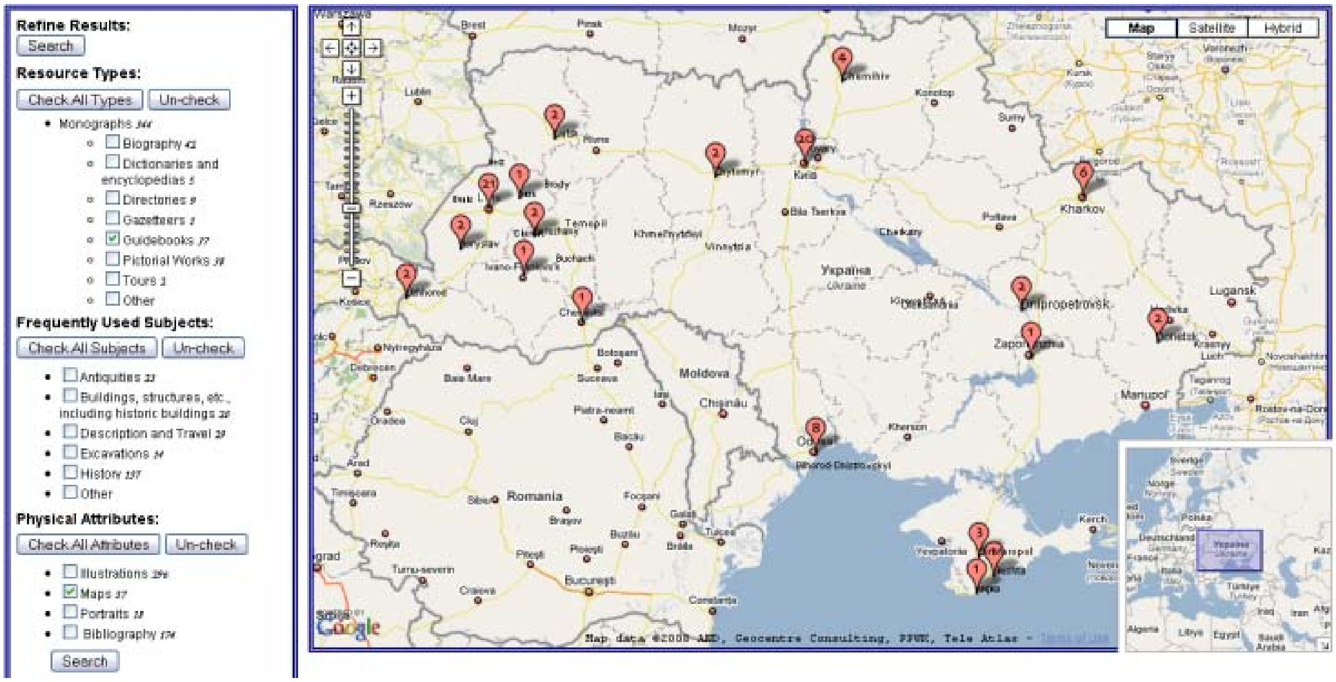


Figure 3. 8 A map with a legend. This snapshot shows what the legend retrieves when users select Guidebooks and Maps categories in the legend.

Representing ontological properties in the legend has many advantages. Without the legend users do not know what is linked to the map-based visualization. Properties allow users to preview hidden structures in the database. Moreover, users can see what properties (subjects, types, and physical properties) appear more than others in the metadata records linked to the LCC DK508 class. In other words, the legend serves as a semantic lens for these records.

While visualizing entire library collections, in which many other similar classes (i.e., mini-ontologies about the Local History and Description) can be found, the legends may be adapted dynamically to include only categories extracted from the metadata MARC records associated with each mini-ontology in the LCC. It is highly possible that mini-ontologies could be associated with slightly different forms, subjects, and physical properties of documents. Some of the advantages of using dynamic legends are: 1) they demonstrate the association between the LCC classes and geographic regions that they describe; 2) they generalize the structure of each class in the LCC; and, 3) they allow users to observe differences in ontological properties among the LCC classes. For example, in MARC, there are as many as 484 discreet language codes (Library of Congress Network Development and MARC Standards Office 2007). It is unrealistic to include all of them in a static legend next to the map. Moreover, not all of these languages are relevant to each geospatial region. Self-adapting legends allow each geospatial region to be associated with a unique set of languages relevant only to that region.

In addition, self-adapting legends enable users to pose complex dynamic queries using a mouse, knowing neither the details of the underlying database schema nor the details of first-order logic. They allow users to select on any legend element and, thereby, set the query parameters to the values of the properties of that element. Furthermore, a self-adapting legend, as conceptualized in our prototype, serves as a control mechanism that allows users to regulate how many objects to retrieve on the map. If too many items are retrieved, the query parameters on the legend can be adjusted to make the number of results smaller. Conversely, when no items or just a few items are retrieved, more relevant criteria can be checked on the legend.

Together with quantitative symbols, the legend facilitates the visual exploration of the retrieved results, which is supported by elementary and synoptic tasks. Together, they allow users to immediately preview how items are distributed and decide whether the number of results is satisfactory or not. They allow users to discover relationships between topical subjects (e.g., history or archaeology) and geographical subjects, as well as forms of documents and their geospatial distributions.

Our legend is different from traditional legends by the nature of the categories (or ontological properties) it represents. While traditional maps have non-overlapping categories (one object has one attribute), on our map categories can overlap in metadata records. One metadata record can have one or more physical attributes, one or more subjects, and one or more forms/genres. This means that theoretically, regardless of how many categories are specified in the legend, only one item on the map can be retrieved. For example, Figure 9 demonstrates what the legend retrieves if we select *guidebooks* (the count for which is 37) and *maps* (the count for which is 57). Logically, users would expect the total number of retrieved results to be the sum of these two, which is 94. But adding up the numbers on quantitative symbols gives us the surprising result of 82, an explanation for which is that 12 guidebooks have maps.

A limitation of our legend is that it allows adding parameters with only the Boolean operator "AND", with no option to search and retrieve items excluding some of these criteria. Graphical representation of Boolean queries is still an open research question in information visualization.

3.3.2.5 Legends and Graphical Representations

Legends can include both textual and graphical representations. Sometimes graphical representations can completely replace text as spatializations, generalized graphs (e.g., trees and networks), or self-organizing maps such as Kohonen maps or tag clouds. These graphical representations in legends have both advantages and disadvantages. Their advantages include providing users with an additional view using a single visualization that captures a complete picture of the data space. The scalability issue in generalized graphs, spatializations, and tag clouds is a major disadvantage for the visualization of subjects from library catalogues (Chen C. 2004; Chen C. 2005). Even in our dataset comprising 343 records, the number of distinct subjects is 574. Presenting all of these subjects next to a geographic map would not be effective. First, there would not be enough room for displaying a large network of subjects. Second, a single global tag cloud as a primary means of partitioning is imprecise and has low recall (Hayes et al. 2006). Third, even if they are displayed, many low-volume subjects do not have labels, which renders them almost useless to users.

To reduce the complexity of graphs, spatializations, and tag clouds, researchers in information visualization and geovisualization have proposed several solutions. Information visualization researchers suggest to divide (or filter) representations into smaller components, to prune (Chen C. 2004), or to thematically cluster them (Lohmann et al. 2009; Hayes et al. 2006). Thematically-clustered tag clouds can assist with discriminating secondary information to further refine and confirm the knowledge produced by the clustering. Furthermore, clustered clouds establish topic-based relationships between tags that were not observable when considering global tag clouds alone (Hayes et al. 2006). Geovisualization researchers use zooming and panning into relevant areas of spatializations or graphs (Hubmann-Haidvogel et al. 2009), or filter representations by time (Stryker et al. 2008). Although useful, such geovisualization techniques have a few shortcomings. For example, in zooming and panning, visualizations focus on certain areas of graphs, spatializations, or tag clouds; as a result, the focus does not include all relevant information; additionally, time-filtered tag clouds may not show thematic relationships among topics.

Pruning and dividing the graphs can be useful for the visualization of subjects in legends. For example, subjects in MARC records include not only topical subjects (e.g, history and archaeology), but also geographic subjects. Showing geographic subjects in the legend might not be necessary, since each geographic subject will be shown on the map anyway. Another type of pruning and filtering can be achieved through a different type of linking. As explained above, legends are usually linked to maps through repetition and are synchronized with maps. In addition, GM provide other linking possibilities; namely, additional graphical representations can be linked via information windows for each city. Each representation linked to a city this way will automatically have a smaller number of subjects (or any other ontological properties) to display, simply because it will be a representation of one city, not the entire mini-ontology (see filtered Kohonen map in Figure 3.10). The downside of such linking is that it will be difficult to compare representations linked to different cities. But it is unclear whether comparisons among collections for different cities are relevant to the map-based visualization of ontological properties of documents. Such comparisons are crucial for the analysis of geospatial phenomena, but probably not as crucial for comparisons of ontological properties.

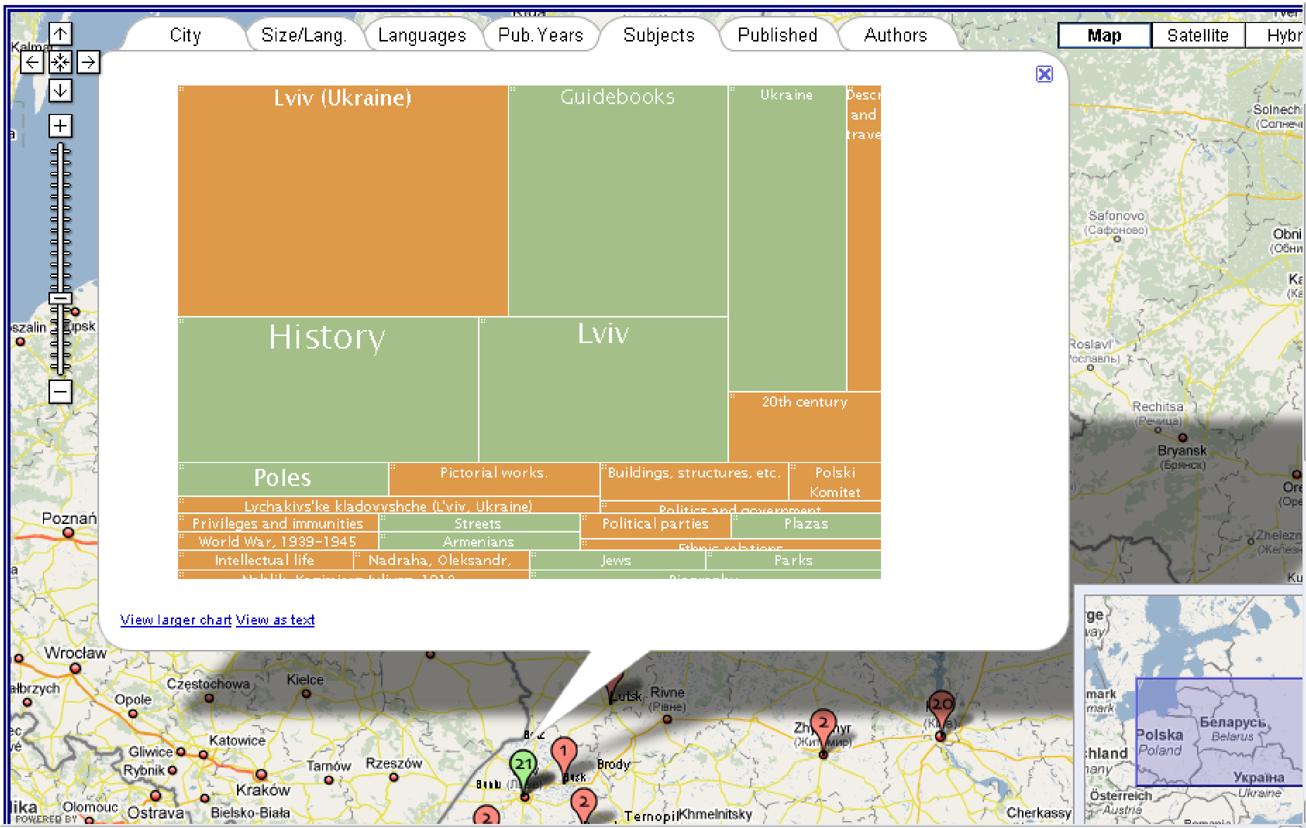


Figure 3. 9 Filtering Kohonen Maps by linking to information windows in GM. This figure shows how graphs, spatializations or Kohonen Maps can be filtered by placename and linked to information windows for each city.

3.3.2.6 Additional Representations

Kohonen maps, graphs, spatializations, and tag clouds are not necessarily the best representations of ontological properties of documents. Other graphical representations may be better at providing insight into other document properties at a glance (e.g., book formats, languages, authors, etc.). The strength of such an approach is the possibility of quickly imparting the various aspects of the collection structure from KOS to users .

The first additional representation which we suggest to add to map-based visualizations is the scatterplot. The scatterplot is one of the most powerful tools for data analysis (Cleveland & McGill

1984) due to its simplicity, familiarity, and visual clarity (Elmqvist et al. 2008). Scatterplots are distant relatives of maps, since like maps they map the information space onto a two-dimensional space (Friendly & Denis 2005). Much like maps, scatterplots show the amount of association between variables, the dependence of variables, cluster of points, outliers, among other things (Elmqvist et al. 2008).

Scatterplots assign data dimensions to graphical axes and render data cases as points in the Cartesian space defined by the axes (Elmqvist et al. 2008). To map categorical values onto scatterplots, designers often transform nominal values by changing them to numbers (i.e., assigning order and spacing to the nominal values) (Rosario et al. 2003). Such transformation procedures allow scatterplots to be used extensively in information visualization (e.g., Ahlberg et al. 1992; Ahlberg & Shneiderman 1994a; Ahlberg & Shneiderman 1994b; Kang & Shneiderman 2000; Nowell 1997). The number of dimensions that a single scatterplot can reliably represent, however, is considerably less than many realistic datasets. To rectify this, scatterplot visualizations often give some control to users to dynamically switch between the visualized dimensions (Nowell 1997). For example, in (Nowell 1997), possible combinations of axes are: document type and relevance, author and publication year, and index terms and relevance.

Among ontological properties in our collection, however, we have two numerical variables which naturally possess the inherent order, spacing, and distance necessary for being mapped onto scatterplot axes. These properties are: the number of pages of a book and its height. Both of these properties suggest the shape or format of the book. Following Tufte's recommendation "If the nature of the data suggests the shape of the graphic, follow that suggestion" (Tufte 2001, 190), we plotted book width on the x-axis, and height on the y-axis (see an example in Figure 3.11). Our scatterplot positions books in a metaphorical space that provides insight about individual book sizes, similarities, and dissimilarities among books in terms of their formats. The representation of book sizes on the scatterplot helps users direct their attention to items of interest, to oversized books, or thick books, just as users would do this if books were placed on a bookshelf. It also allows users to draw conclusions about the average book size and the outliers.

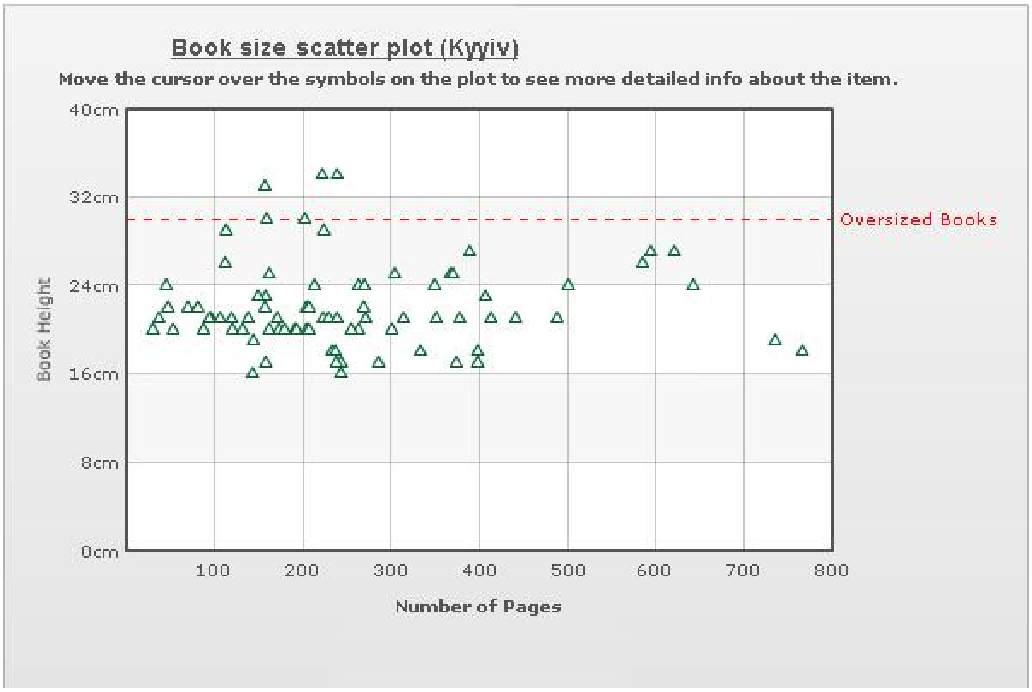


Figure 3. 10 A book size scatterplot. This figure shows sizes of 89 books. From this scatterplot users may conclude that approximately two-thirds of all books have fewer than 300 pages; 3 books are taller than 32 cm; and 6 books have more than 500 pages. The height of most books is around 20 cm.

Using symbols, small icons, or letters to encode their datapoints, scatterplots can expand their analytical affordances. Namely, they can assist users with perceiving the point cloud of a particular category as a unit as if the other points were not there. There is a great variety of techniques available to represent datapoint categories. They are letters, filled or unfilled simple geometric shapes, simple shapes such as the circle and regular polygons, sunflowers (Cleveland & McGill 1984), points of the same subset connected by lines (Becker et al. 1987), radial line symbols, the plus sign, or the asterisk (Tremmel 1995). For example, Figure 3.12 shows how languages can be encoded as geometric shapes of different colours. Colour-coded shapes will help users see hidden properties of items and will help them relate similar objects, determine relevant objects, and perceptually estimate the distribution of relevant items without any extra cognitive effort. Coloured lines between symbols can be used for encoding bibliographic relationships among various editions or other manifestations of bibliographic works, if items have different dimensions. In addition, symbols can have built-in textual descriptions of items to scaffold users in the interpretation of graphics (e.g., titles, years of documents, or even thumbnails) and may have graphically represented links to other expressions of the same bibliographic work (e.g., videos or CDs). If more than one document has the same dimensions, the symbol size can be used to encode multiple documents.

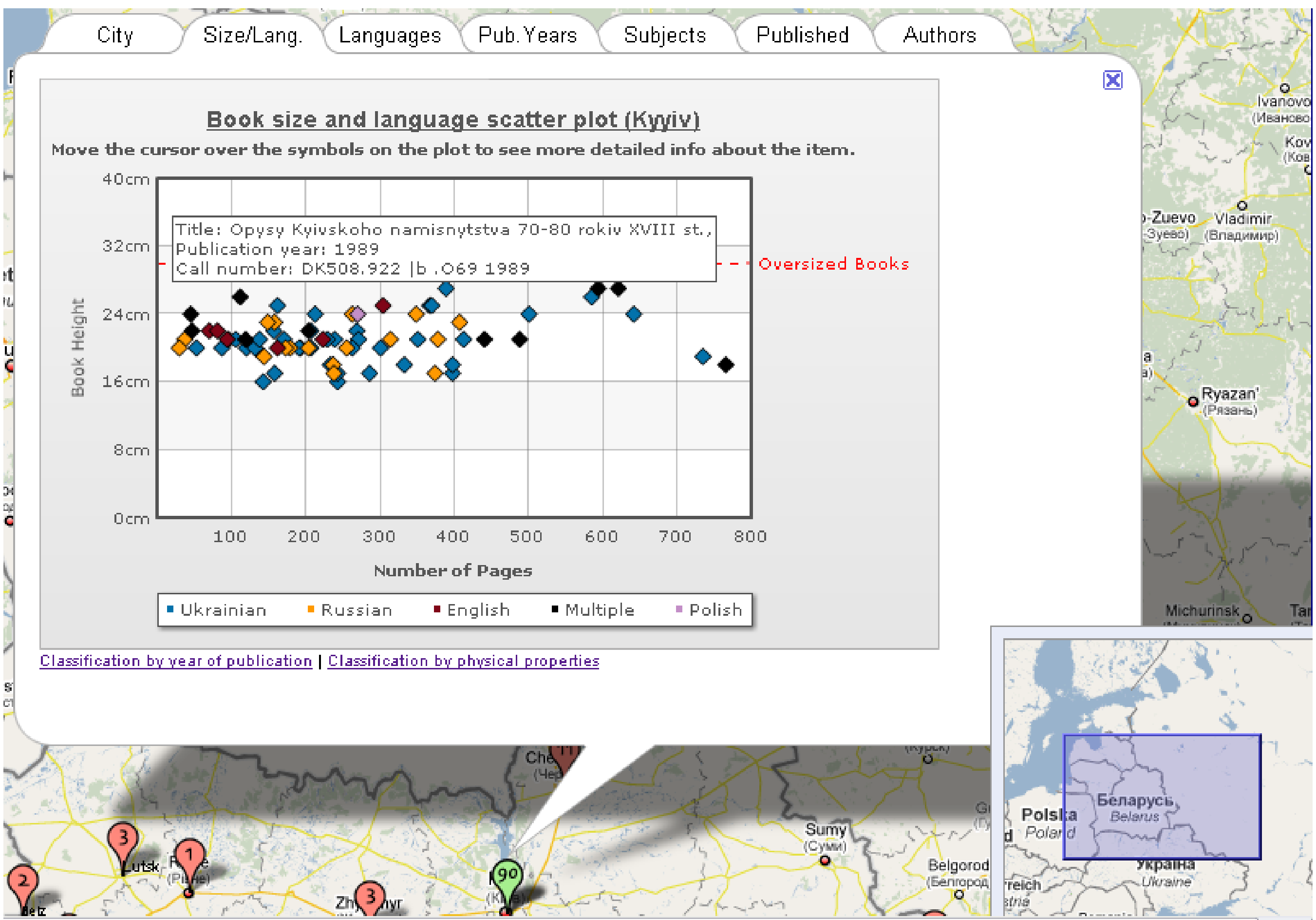
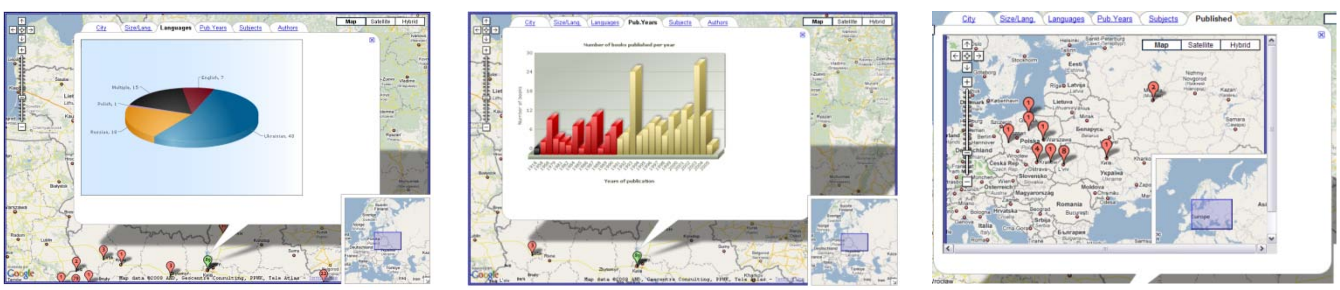


Figure 3. 11 A colour-coded scatterplot. Colour-coded geometric shapes on this scatterplot show languages of documents about Kiev. There are a few items in Russian, English, and Multiple languages.

Other supplementary representations that can be useful are pie-charts, histograms, and embedded geographic maps. These representations may be used for representing languages, local timelines, and even geographical maps (see Figure 3.13). Each of these representations reveals the structure of separate ontological properties and supports different visual tasks. Thus, the pie chart, unlike the scatterplot, shows the proportion of languages in the whole set (see Figure 3.13.a). This representation supports quantitative comparisons of documents based on languages.

Histograms may show local timelines (see Figure 3.13.b). While global timelines for publication and acquisition years record purchasing and publishing events in the entire DK508 mini-ontology, dynamically-generated local timelines, linked to information windows for each city, can expose chronological gaps, temporal extents, and currentness of datasets for each city. For example, in our dataset, histograms for each location vary by the start date. For some places, the Library of Congress has resources published in the 19th century (e.g., Odessa's collection was published starting from 1837), while for others the first collected items were published more than a century later (e.g., Kharkiv's collection starts from 1986). Furthermore, each location may have its own set of historical periods (or events), which can be added to KOS for visualization purposes, with historical time periods being colour-coded. For example, the vertical bars in the Kiev histogram show such time periods as "before the October revolution of 1917" (shown in black), "the Soviet times" (shown in red), and "after 1991" (shown in yellow). Colour-coded histograms not only can show statistics and assist with quantitative comparisons, but also may emphasize trends in publishing (e.g., during the Soviet times, the publication rates about local history were low, and they became higher after 1991 when Ukraine became independent).

Geographic maps can be used to provide links to themselves. This is possible since documents have two major geographical properties. The first is the geographic aboutness, which is about subject or content; the second is the geographic place of publication. Typically, map-based visualizations provide equal access to the geographic aboutness and the place of publication, and users are allowed to switch between these two maps. However, when not viewed together, users are limited in the visual tasks they can perform. The map of publication places allows users to determine the spatial distribution of publishers and possibly the volume of documents purchased from each publisher, and the map of geographic aboutness allows users to see the distribution and density of geographical subjects. But when publication places are coupled with geographic aboutness, they can tell users much more. In particular, they can tell users information such as where books about a particular city were published. For example, the map of publication places in Figure 3.13.c shows users that half of travel guides and items with maps about L'viv were published outside Ukraine, with 9 items published in Poland. Such multiplicity and crosslinking of representations, we argue, extends the utility of map-based visualizations, supporting a more diverse set exploratory and visual tasks to be performed on document collections.



a) b) c)

Figure 3. 12 Additional representations: a) a pie chart showing languages of documents about L'viv; b) a histogram of publication rates by year (city Kiev); c) a map with places where documents about L'viv (Travelguides and items with maps) were published.

Besides these representations, map-based visualizations can have links to graphical representations of bibliographic works and citations. Bibliographic works can be represented as tree-like graphs that sort and arrange bibliographic record sets according to the FRBR model (one such visualization is described in Leazer & Furner 1999). In our prototype dataset, however, the majority of bibliographic works have a single manifestation. This is not surprising, according to a study by Bennett et al. (2003), 78% of works in library catalogs have a single manifestation. The works that have the most manifestations can probably be found in other parts of a collection such as literature, psychology, and religion. Self-adapting legends in map-based visualizations can possibly facilitate visualization of FRBR model in the contexts where it is relevant and omitting it in the others.

In addition, map-based visualizations can be linked to citation maps represented either on a Self-Organizing Map, or with a means of factor analysis, multidimensional scaling, or eigenvalue decomposition techniques (Börner et al. 2003). Such geospatially-contextualized citation maps can help reveal the role of culture, identity and collaboration in the research communities (Chen et al. 2008).

It is important to note that it was difficult to add disciplines to the visualization at this stage. The problem is that disciplines are at the very high level in the LCC. The documents presented in this paper are all about history and they are linked to the lower-level classes in the LCC.

Last but not least, it is assumed that all the representations discussed in this paper are interactive. Static, non-interactive, representations are limited in aiding human cognition (Spence 2007). Interactions should at least enable users to probe and retrieve different elements of the map-based visualizations. Otherwise, much of the semantic and relational properties of these visualizations will remain hidden and latent (Sedig & Sumner 2006).

3.4 Conclusions and Future Work

Throughout this paper, we have drawn attention to two research issues concerning map-based visualizations. The first research issue is the need to extend map-based visualizations to include representations that encode ontological properties of documents. The proposed representations in our prototype are not necessarily the most usable, effective, or efficient representations of ontological properties. Testing is underway to determine effectiveness of these representations. The second research issue, tightly coupled with the first, is the need to take into consideration visual tasks that can be supported by visual representations. Currently, when designers create map-based visualizations of documents, they are primarily concerned with mapping individual items on digital maps. They are less concerned with how people understand these items, and what visual tasks these mappings can facilitate. To overcome these limitations, we need to reconceptualize map-based visualizations in the context of representations and visual tasks. This clearly points to the need for design frameworks for map-based visualizations, classifying representations and their associated tasks. Developing such taxonomic design frameworks should be an important objective of map-based visualization research.

Ultimately, map-based visualizations need to address a fundamental question about how computers can amplify human cognitive and epistemic abilities. In the context of geospatial references, visualizing concepts and time periods is an insufficient goal. Map-based visualizations must also aid users in performing epistemic activities, such as making sense of linked library collections and generating hypotheses about collections.

The visualization of ontological properties of documents may take many forms and this paper has only provided an introduction to such visualizations. Due to the limitations of our prototype dataset, we were not able to demonstrate how map-based visualizations can be augmented with the representations of citations, bibliographic works, disciplines, and some other document properties. It is hoped that further research will construct and test more sophisticated visualizations that incorporate additional ontological properties and support other visual tasks and epistemic activities. This will improve the design of map-based visualizations and facilitate rich interactions with geospatial data.

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Chapter 4: Making Sense of Document Collections with Map-Based Visualizations: The Role of Interaction[1]

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Abstract

Introduction: With wider availability of digital maps,[1] interest in map-based interfaces for digital libraries has recently surged. However, this interest has usually been limited to creating simple map-based interfaces with minimal interactions that provide insufficient support for higher-level knowledge activities such as sensemaking. An example of sensemaking is collection understanding. To understand a georeferenced collection not only means getting insight into the geospatial aspect of the collection, but also getting insight into other aspects such as the structure, properties, relationships, processes, and complexity of the underlying information spaces.

Background: The major reason why many aspects of georeferenced collections remain cognitively inaccessible to users is the lack of or small number of human-information interactions in simple map-based visualizations. We conceptualize such interactions as small actions and their subsequent reactions (e.g., filtering, selecting, gathering, and others). Although these actions may not be viewed as direct contributors to enhancing understanding, in reality they simplify and enhance sensemaking activities incrementally, by helping people prepare objects for visual tasks and ultimately higher-level sensemaking.

Method: A prototype, VIsual COLlection EXplorer (VICOLEX), has been developed and implemented to examine the role of interaction with representations in facilitating the understanding and making sense of document collections.

Analysis. VICOLEX was used to make sense of a prototype collection, a Local History collection from the Library of Congress catalogue.

[1] e.g., Google Maps, Google Earth, Bing Maps, and others

Results. An informal testing of the prototype is presented in this paper. The results of this testing include observations of transitions, trends, patterns, and hypothesis about the properties of the collection and locations that the collection represents.

Conclusion. Interactions with representations in VICOLEX play a crucial role in making sense of the prototype collection. The research ideas discussed in this paper can potentially be applied to visualization tools and information interfaces that are intended to support all kinds of knowledge activities involving georeferenced information.

4.1 Introduction

Map-based visualizations (MBVs) as information interfaces to geodigital libraries are new. Such interfaces display geospatial locations referenced in document collections on digital maps. In MBVs, user engagement with the underlying information is mostly facilitated through searching and browsing (Panel on Distributed Geolibraries, 1999). Such interactions are performed not only through conventional text-based forms, but also through graphical interfaces. For instance, geospatial searching can be specified by drawing a bounding box or a circle to encompass an area of interest on an MBV (Hill, 2006); geospatial browsing of documents is performed through interactive selectable links (Larson, 1996); and, temporal searching is supported by zooming in on an area of interest, or sliding a time bar to the period of interest (Zerneke, Buckland, & Carl, 2006). While such interactions are useful for supporting tasks that are traditionally performed with library catalogues, we do not believe that they provide sufficient support mechanisms for carrying out higher-level knowledge activities with MBVs (e.g., making sense of document collections).

In addition to searching and browsing, some researchers have also investigated how MBVs can support visual tasks. For instance, Buchel and Sedig (2011) have discussed the necessity of providing support for low-level visual tasks such as identifying, comparing, locating, and associating. Visual tasks are the constituent components of higher-level activities such as knowledge discovery (Koua, 2005), geospatial exploratory analysis (Andrienko & Andrienko, 2007), and sensemaking (Russel, 2003). However, regardless of how well MBVs support visual tasks, many of them still have severe limitations. This is because even the most thorough perceptual analyses of the shape, color, and other visual attributes of visualizations do not guarantee that users can understand the visualized documents or collections. As Kaptelinin & Nardi (2009) point out visual perception is not sufficient for understanding and sensemaking; such activities require interaction with the world at a higher level. When performing such activities, interaction allows users to change their working environment, customize how the information space is displayed, seed cues about possible next steps in the sensemaking process, and adapt information from documents to needs (Russel, Stefik, Pirolli, & Card, 1993; Kirsh, 2009; dos Santos, 2004; Dillon, 2000; Fast & Sedig, 2009).

With the above in mind, the goal of this paper is to examine the role of interaction in enhancing the utility of MBVs for supporting sensemaking activities. Sensemaking refers to a broad set of activities which involve many different phenomena and information spaces. For example, when we move to a new neighbourhood, we try to make sense of its streets, schools, parks, stores, and neighbours. When we are deciding on buying a new car, we need to make sense of car prices, specifications, and reviews. In this paper, we concentrate on a very specific instance of sensemaking: making sense of a collection of documents, or in other words, collection understanding. Our examination of interaction and how it can enhance the utility of MBVs for supporting collection understanding is in the context of human-computer interaction (HCI) community's conceptualization of sensemaking.[2] To do our examination, we will present, define, and examine a number of concepts and ideas dealing with the design of interaction for MBVs using an example prototype system, VICOLEX (VIsual COLlection EXplorer). VICOLEX is a prototype MBV that we have designed and implemented to help users make sense of a collection of

[2] It is important to note that sensemaking in HCI is distinct from sensemaking in LIS and Organizational Theory conceptualized by (Dervin, 1992) and (Weick, 1995). The latter theories are outside the scope of the research presented in this paper.

records from the Library of Congress catalogue. As VICOLEX is a testbed for our examination of the role of interaction, our goal in this paper is not to evaluate its quality empirically. Rather, our examination is analytical and we use empirical evidence and studies by others to justify many of the presented ideas. Additionally, we intentionally omit discussion of searching and browsing by space and time as these topics have been extensively covered in previous research by others (see for example, Hill, 2006; Pequet & Kraak, 2002; Edsall, 2001; Zerneke et al., 2006; Li & Kraak, 2008).

The remainder of the paper is divided into five parts. In the next section, we provide some conceptual and terminological background about MBVs, document collections, information spaces, interactions, tasks and activities, sensemaking, and collection understanding. Then we describe the prototype collection that we have used. Afterwards, we analyze the prototype collection with the goal of investigating how collection understanding can be facilitated. We then turn our attention to an analysis of VICOLEX and its features, focusing on interactions and their role in making sense of collections and locations. Then, we briefly present how interactions can be combined to perform higher-level activities with VICOLEX. Finally, in the last section, we provide a summary of this research and briefly discuss its applications and outline some future lines of research.

4.2 Background Information

4.2.1 Types of MBVs

Based on the degree of complexity of interactions and representations, we distinguish three major types of MBVs: simple, space-time-topic, and complex.

Simple MBVs. Simple MBVs usually have a digital map with only searching and browsing. Users can submit their queries in the search box and retrieve the results displayed on the map. An example of such interfaces is Globetrotter of the Alexandria Digital Library (ADL), http://clients.alexandria.ucsb.edu/globetrotter/. Simple MBVs are good at making geospatial relationships visible. For instance, Globetrotter visualizes geographic locations captured in the ADL collections (i.e., aerial images, digitized maps, and other documents). The shortcoming of such interfaces, however, is that they do not visualize any other document properties, such as subjects, time periods, languages, years of publication, and authors. The metadata records of the visualized documents can only be viewed individually instead of as a set; this does not allow for distinguishing and grouping documents based on commonalities and idiosyncrasies. Furthermore, it is often difficult to analyze, make sense of, and reason about these MBVs due to their complexity, visual clutter, and marker density.

Space-time-topic-centered MBVs. Space-time-topic-centered MBVs focus on the visualization of geographic space, time, and topics or themes of a given collection. Representations in such MBVs include synchronized geospatial maps, semantic views, and timelines. An example of such interfaces is the Health GeoJunction web portal, http://www.apps.geovista.psu.edu/hgj/. This MBV has a digital map synchronized with a Tag Cloud and a timeline. All individual views (the map, the Tag Cloud, and the timeline) are generated from the entire collection of documents, and therefore are semantically equivalent (i.e., it is easy to establish relationships between representations of entities in one view with different representations of the same entities in another view). The merit of this type of interface is that it shows interrelationships among three ontological properties of documents: geographic space, time, and topics (Andrienko & Andrienko, 2007). Any change in any of these properties is reflected in the representations of other properties. Such interfaces are suitable for making sense of geospatially-distributed information. However, they are not as useful for making sense of other information contained in documents. The advantage of this type of visualization is that it provides a rather comprehensive picture of the data; users can see a complete overview of every representation and can clearly observe what impact changes in one representation make on another. Problems include the lack of screen space, the counterintuitive and cognitively-overwhelming interface that requires users to learn complex constructs (Baldonado et al., 2000). Users frequently need help understanding the interface, locating the main widgets, demonstrating their manipulation, and explaining the resulting actions (Andrienko & Andrienko, 2007).

Complex MBVs. Complex MBVs make salient a greater number of ontological properties of collections than space-time-topic-centered MBVs. In such visualizations, ontological properties of documents linked to each location are represented with additional representations. For instance, a marker on the MBV can be linked to many additional representations: a scatter plot, a histogram, an embedded map, and a Kohonen map (e.g., see Buchel & Sedig, 2011). At first glance, complex MBVs might appear to be similar to space-time-topic-centered MBVs because of multiple representations. But they are different by the technique how these multiple views are linked and what they represent. The main difference is that multiple views are not semantically equivalent because the main map shows the entire collection, and the multiple representations show properties of collections about distinct geographic locations (i.e., they show subsets of the entire collection). Second, multiple views in the complex MBVs are used minimally (they are shown one-at-a-time), hence providing users with a stable context for analysis of properties (Baldonado et al., 2000). In complex MBVs, the additional representations scaffold visual comparisons of geographically-distributed collections and assist with making sense of the underlying structure and patterns in these collections. The advantage of these interfaces is that they enable users to see a variety of ontological properties of geospatially-distributed collections such as languages, years of publication, book sizes, and authors. Here, collections are sets of documents linked to each geographic location. All these additional representations are linked to geographic locations via multi-tabbed information windows. Complex MBVs can have both positive and negative effects. Their positive effects are related to multiple views of geographically-distributed collections that can help users partition complex data into manageable chunks, and to “divide and conquer" a single complex view, hence reducing clutter and information overload (Baldonado et al., ibid.). Their negative effects are associated with prevention of comparisons between multiple-linked views. It means that previously-viewed, relevant representations must be held in one's memory if they are to be integrated with new knowledge (Wilhelm, 2008).

4.2.2 Document Collections

In order to improve the design of MBVs, it is important to clearly define and conceptualize document collections. The library and information science community has never universally agreed upon a definition of the concept of collection (Lee, 2000; Hill et al., 1999). In traditional libraries, collections are closely associated with library holdings. Collection developers, however, use the term slightly differently. For example, when they acquire new sets to add to a larger collection, they refer to these acquired sets as collections but may still think of them as sub-collections, even though they are integrated into a larger collection. In digital libraries, any set of objects can be considered a collection, not just those physically owned by the library (Hill et al., ibid.). These definitions then view a collection as a single entity that hardly has any structure or properties. A different perspective on collections views them as "contexts for information seeking" (Lee, 2000). As such, collections have their own communities of users and are characterized by thematic cohesiveness. Such collections are composed of multiple entities with unique ontological properties. Ontological properties group together and capture in metadata records publication years, places of publication, editions, titles, subjects (including geographic subjects), authors, publication types, call numbers, publication languages, relationships with other documents, height of the book, descriptions of illustrative matter (presence of illustrations, maps, portraits), bibliographic notes, and others. Even though properties of smaller collections might be different from those of whole collections, removal of the former may cause properties of the latter to change both quantitatively and qualitatively.

Collections have structure—i.e., deliberate form, arrangement, and organization. Structure serves to identify, highlight, and clarify the essential features, properties, and relationships of both collections as well as documents within the collections (Fast & Sedig, 2005). Classifications aim to capture the structure of collections. Classifications such as Library of Congress Classification (LCC) and Dewey Decimal organize collections into hierarchies. Lee (2003) explains and illustrates that collections coexist in multiple layers — their multi-layered hierarchical structure — (i.e., some collections are sub-collections of others). For example, in academic libraries, collections can be separated into a number of physically-dispersed sub-collections, such as the social sciences, medicine, and engineering. These sub-collections can be divided into smaller sub-collections (e.g., about geographic locations or other themes). It appears that collection layers correspond to classes and schedules in classifications (e.g., social sciences collections can be found in H schedule of the LCC, and history in D-F schedules of the LCC). Saliency of structure is central to how collections are conceptualized in MBVs, because each structure can make explicit what can otherwise remain implicit, tacit, or latent (Fast & Sedig, 2005), namely collection contexts, properties, similarities/dissimilarities, and trends. In the context of MBVs, when collection structure is made salient, it allows users to view collections linked to individual locations as smaller sub-collections with rich ontological properties not just as a group of separate documents that are hardly associated with each other. Properties of sub-collections facilitate identification of trends, similarities, and idiosyncrasies in sub-collections about different locations. Sub-collections may have strengths and weaknesses, can be unilingual or multilingual, can be published in one or many countries, can be current or outdated, and can have some subjects or authors represented better than others.

Collections have a transitional nature—i.e., they change due to the addition and deletion of documents to and from them (Currall, Moss, & Stuart, 2005). Transitional processes in general involve movement, development, evolution or change (Sedig et al., 2005). Transitional processes in collections are caused by acquiring, weeding out, and borrowing. Some of these transitional processes are temporary (borrowing), others are permanent (acquiring and weeding out). Most of these processes are multidirectional, as they move along several directions (ibid.). Given a particular starting state, the transition can take different courses to one or many sub-collections. As a result of transitions, some collections grow, some shrink, and some remain unchanged. Transitional processes have a direct effect on properties of collections. All additions to or subtractions from collections and sub-collections are reflected in their properties. They can increase, decrease, or remain unchanged. But even if sub-collections remain unchanged while others grow, the relative share of the unchanged sub-collections may become smaller due to the growth of other sub-collections. Transitional processes are not always easy to understand. Often they remain “hidden” (Dodge & Kitchin, 2001), and can only be understood using properly-designed interactive information interfaces (Sedig et al., 2005).

Understanding georeferenced collections would be incomplete without placename gazetteers with descriptions of geographic locations, which can have a structure of their own with properties such as location placename, variant names, footprint, and category (Hill, 2006). Properties of geographic locations may help differentiate locations and identify physiographic features of various types (e.g., lakes, bays, fijords). In addition, digital maps reveal many other properties of geographic locations in a graphical form (e.g., distance, size, direction) which enhance understanding of geographic aboutness of collections. For example, while from document collections users can learn how big a particular collection is and what properties it has, from the descriptions of geographic locations users can learn more about locations (i.e., population size, history) and associated properties of locations to those of collections.

4.2.3 Activities, Tasks, and Interactions

Thus far, we have discussed the structure, properties, and transitional processes of document collections. Making these visually accessible can facilitate understanding. But collection understanding does not stop here. Users perform activities and tasks with them. In the context of this paper, activities and tasks refer to what people do with the document collections (Fast & Sedig, 2005). Activities are undertaken by human subjects motivated towards objects producing outcomes and mediated by tools and environments (Kaptelinin & Nardi, 2009). For example, topic comprehension (Qu & Furnas, 2005), exploratory data analysis (Pirolli & Rao, 1999), literature review (Zhang, Qu, Giles, & Song, 2008), collection understanding (Chang, et al., 2004), and document triaging (Buchanan & Loizides, 2007) can be regarded as activities.[3] Activities are often comprised of lower-level tasks. Tasks are conscious, goal-related processes that must be undertaken to fulfill a goal. Tasks can be decomposed into subtasks, subsubtasks, and so forth. For example, preparing documents for writing a report is a task that entails a lower-level subtask: finding suitable topics to cover in the report along with suitable citations and quotations. Therefore, tasks are hierarchically organized and can be decomposed into an arbitrary number of sublevels, from higher-level tasks (e.g., identifying the structure of the topic) to lower-level subtasks (finding and grouping citations and quotations).

In 2D MBVs, different aspects of information are encoded using different representational forms (e.g., graphs and additional layers on maps). Each form is suitable for some specific tasks. For example, a tree can show the hierarchy of collections and a map their spatial distribution. No one representation can render the full complexity of information. To overcome this deficiency, users need to interact with representations. For this reason, cartographers (Golledge & Stimson, 1997) say that it is interaction in

[3] In the human-computer interaction (HCI) literature, however, these activities are often called tasks. This is because in HCI there is no clear distinction between tasks and activities; and, therefore, these terms are used interchangeably.

space, not perception of space, which is a fundamental for understanding information encoded in various forms.

To perform tasks, users act upon representations of objects in MBVs. This is done through interface-mediated interactions. An interaction is a low-level action that users perform on representations followed by the response that they get (Sedig, 2009). Interactions allow users to perform physical actions in order to adjust information representation to suit their epistemic needs, making different properties, elements, relations, and layers of information explicit and available on demand. This can potentially enhance users' ability to explore, query, and transform different visualized objects and their properties. There is much evidence that actions have potential benefits for cognition. They help users externalize thought, reduce cognitive load, simplify perception and mental computation (Kirsh & Maglio, 1994; Kirsh, 1995), gather rich sensory information from the environment (Klemmer, Hartmann, & Takayama, 2006), and give rise to otherwise unavailable perceptual information (Kirlik, 1998). An example of the benefits of actions is when playing the game *Scrabble*. In this game users act upon the letters to generate words: they move them around, cluster them, and rearrange them. It has been found that using such actions users generate more words than without them (Maglio, Matlock, Raphaely, Chernicky, & Kirsh, 1999). Kirsh and Maglio (1994) refer to these actions as *epistemic actions*, as they help people with the performance of mental tasks.

4.2.4 Sensemaking

Sensemaking activities are usually characterized as ill-structured, open-ended problems. For example, exploring genealogy of family history, tracing history of remote places, and gathering information about places of interest for a trip are sensemaking activities that are ill-structured, open-ended problems. Sensemaking activities involve users establishing some goals, discovering an information space's structure and texture (e.g., vocabulary), figuring out what questions to ask, and determining how answers to those questions are to be organized (Russel et al., 1993). The outcome of sensemaking activities depends on how well users perform these tasks.

Sensemaking activities are distinct from information seeking activities in which the goal is to locate a specific, well-understood piece of information. In sensemaking, users must make sense of potentially-conflicting pieces of information scattered across many documents. To expedite and scaffold sensemaking activities, users oftentimes rely on various representations—both internal cognitive structures as well as external resources such as tables, graphs, or other graphical encodings of information. Users seek external representations in seemingly-unstructured situations and use them to organize information in service of the sensemaking activity (Russel et al., 1993). External representations can help users conceptualize a problem and form internal representations, make sense of a situation, and formulate actions rapidly. Moreover, representations provide constraints for users, dictate which operations should be performed next (Furnas, 2008), and facilitate planning and reasoning about alternative courses of action (Pirolli & Card, 2005).

Sensemaking involves a constant search for new representations. When encountering representations that do not fit into their internal representations, users often search for better representations (Russel et al., 1993), an iterative process in which users start with simple undifferentiated representations and, after a series of steps, end up with more complicated, elaborated, and refined ones (Furnas, 2008). In the case of document collections, representations commonly encode only a subset of their aspects and support only specific tasks (e.g., answer specific questions). Documents, however, may have information with many implicit, internal, and/or latent layers of meaning, structure, and patterns that cannot be easily encoded at a perceptible level. In the process of sensemaking, the lack of ability to penetrate the deeper layers of information may result in disconnects and gaps between users' mental and reasoning processes and representations (Sedig, 2009). In addition, representations can be visually dense and information rich, in which case the encoded information may not be readily available and perceptible. Working with such representations may require users to perform a great deal of mental unpacking, evaluation, and elaboration (Sedig, 2009). Bringing latent information to a more observable level and separating information objects from their properties can be demanding tasks for users with high cognitive costs (Kirsh, 2003).

To support their sensemaking with representations, users often interact with them. Kirsh (2009) makes a distinction between two major types of interactions with external representations in sensemaking activities. The first type concerns a variety of operations that people perform when *using* representations, such as rearranging or reformulating the representations. The second type concerns those things that people do to *prepare* themselves to use representations, such as gathering documents and placing them into piles or files or using various office supplies to keep related documents together, or preparing documents for “presentation” by making an outline and synthesizing a topic. There is also evidence from interactive information systems and visualizations that suggests that interactions affect quality and speed of sensemaking directly: systems with richer interactions have positive effects, while systems that lack interactions have negative effects on the sensemaking process. For example, Sandbox, an interactive tool for making sense of web pages, expedites sensemaking and improves quality of analysis (Wright et al., 2006), whereas Google Notebook hinders sensemaking (Russel et al., 2008). Users of the latter constantly wrangle with it and have difficulty remaining focused on the activity. Similar to Google Notebook, spatial hypertext visualizations also impede sensemaking if users cannot interactively rearrange hypertext items (Russell et al., 2006). In general, we can conclude that two essential building blocks of sensemaking are representations and interactions.

4.2.5 Collection Understanding

Collection understanding involves encountering a collection and learning about its structure, its theme, its properties, why certain documents belong to it, common features of its documents, and varying qualities linking these documents. Increasing users' awareness to acquire a comprehensive overview of the whole collection helps users appreciate the collection builder's (or curator's) point of view. With such awareness, users may then form their own understanding of the collection and steer subsequent collection-related tasks (Chang et al., 2004). In the context of MBVs, understanding a collection's structure and properties is important (Buchel, 2011), as it is not enough merely to see documents linked to map locations; rather the documents should be viewed as a sub-collection of all documents linked to a map. From this perspective, sub-collections require their own overviews of collection properties and interactions that can help users make sense of collections in particular locations.

Two major approaches have been used to facilitate collection understanding in library and information science: collection-level metadata and visualization. Collection-level metadata represents collections at the aggregate level and provides context for the documents (Zavalina, 2010). In particular, collection-level metadata provides summary of subjects, objects, geographic coverage, temporal coverage, and provenance of the collections. But these representations have two major shortcomings. First, they are in the form of text, which is not good support for the visual tasks necessary for higher-level knowledge activities such as collection understanding (Buchel & Sedig, 2011). Second, they are static—i.e., not interactive. Furthermore, metadata representations cannot be grouped, merged, decomposed, and combined to dynamically generate new temporary ad-hoc collections/sub-collections that would emphasize, reveal, hide, and transform the various properties and relationships of collections. Once a collection is catalogued, it is treated as a monolith that is not to be subject to any changes. The second approach is through visualization, used for generating collection overviews, and it is not always effective either, as interactions are either lacking or inadequate. Examples of such visualizations include hierarchies, trees, paradigms, and faceted classifications (Kwasnik, 1999), concept maps (Shen et al., 2003), or spatializations (e.g., graphs) (Bòrner, 2010; Fabrikant & Buttenfield, 2001) that are used for generating collection overviews; however, these are often static, with minimal interaction: zooming. They cannot be transformed into other representations. Moreover, they represent collections only from a single perspective. This is not sufficient for understanding their granularity, multivariate ontological properties, and contexts. To support understanding of collections (i.e., their sub-collections, properties, and relationships), users need to act upon representations in a variety of ways.

4.2.6 Information Spaces

At the most basic conceptual level, a space is characterized by a complex network of relationships between its components that mirror structure and properties of objects that exist in the real world (Dodge & Kitchin, 2001). There are a few information spaces associated with document collections, such as semantic, geographic, social, and working spaces. In the remaining part of this section we discuss all these spaces in greater detail. A semantic space is related to the structure and properties of documents and collections. One such property is shape. For instance, the shape of a document collection can be represented in the form of graphs and hierarchies in which positions of objects, their proximity, their relations, and their orientations toward one another are determined computationally (Dodge & Kitchin, 2001; Fabrikant & Skupin, 2005). Alternatively, if a collection has geographic references, the semantic space can be overlaid onto a geographic space where the shape of the semantic space becomes more apparent (Dillon, 2000), and the real-world concepts of distance, direction, magnitude and so on take on semantic associations (Deerwester et al., 1990). However, it is important to keep in mind that while semantic and geographic spaces gain new characteristics from merging with each other, they preserve structures and properties of their own.

Besides semantic and geographic spaces, today's document collections can also be social spaces, where users can contribute to and interact with information and with each other (Spiteri, Tarulli, & Graybeal, 2010). Social spaces are constructed by a community of users. In social spaces users can learn about activities of other users in collections (e.g., what other users visited, what they used, what they annotated, and so on). Finally, there are personal places where users creatively appropriate aspects of an information space, organize it, adjust it to their needs, and add their own understandings (Harrison & Dourish, 1996). As such, places are also known as working spaces (Shipman et al., 1999). Once documents or collections of interest are retrieved, users are in constant need of organizing the retrieved information. Organizing and gathering tasks are inherently spatial, involving placing objects somewhere (Kirsh, 1995). These tasks define the geography of working spaces (Shipman et al., 1999). This is because spatial arrangements of objects convey hidden meaning. Closer items can indicate urgency, and piles of items are "automatically" ordered chronologically because new items are typically placed on top (Kirsh, 2001). For instance, larger document size (Kirsh, 2001) as well as document position in space may be indicative of the priority of documents. Such spatial cues help users overcome the inherent inexpressiveness of space that prompts them to the next steps in the task. Overall, we may assume that document collections are associated with four main types of spaces (i.e., *semantic*, *geographic*, *social*, and *working* spaces), which, even though, not exhaustive or universally-recognized (e.g., see Fabrikant & Buttenfield, 2001), help us understand how spaces help users carry out sensemaking activities.

As people make sense of information spaces, they construct internal representations known as cognitive maps (Kitchin & Freundschuh, 2000; Gollidge, 2010). Some researchers think that cognitive maps look like external representations of the spaces they encode—that is, more or less veridical, metric, and unified. Other researchers consider that cognitive maps may be ad hoc collections of information from different sources put together to solve particular problems (Kitchin & Freundschuh, 2000). According to the former view, spatial knowledge is stored in a mental image form; and according to the later, it is stored in both textual and image forms, and both forms can be organized in hierarchies (Pequet, 2002). In terms of their structure, cognitive maps include five main structural components: landmarks, paths, districts, nodes, and edges (Lynch, 1960). Kuipers, Tecuci, & Stankiewicz (2003) suggest another structural component - "skeletons," formed by the network of routes along which a person frequently travels (e.g., subway routes can form a skeleton). Such skeletons play a major part in framing a person's knowledge of the space and help people make navigation decisions (Look & Shrobe, 2007). However, regardless of the seemingly rigid organization of cognitive maps, people's cognitive maps are characterized by various distortions and deformations (i.e., they have holes, folds, tears, and cracks) (Tversky, 1981). For example, people make mistakes in remembering actual distances, alignments, and directions in space.

4.3 VICOLEX

VICOLEX (VIsual document COLlection EXplorer),[4] a prototype interface, is an interactive MBV for supporting the activity of sensemaking involving document collections with geospatial references. VICOLEX is built using Google Maps (GM) API Version 2.0, PHP, Ajax, Fusion Charts,[5] Geometry Controls,[6] and DragZoomControl.[7] The ideas and principles outlined in this paper could be implemented using any other geographic information system; however, we chose GM API Version 2.0 because this API already supports a host of interaction techniques and has an extensive function library that can be used to design different interactions.

[4] http://abuchel.apmaths.uwo.ca/~obuchel/maps/VICOLEX.php

[5] http://www.fusioncharts.com/

[6] http://gmaps-utility-library-dev.googlecode.com/svn/trunk/geometrycontrols/

[7] http://gmaps-utility-library.googlecode.com/svn/trunk/dragzoom/1.1/docs/examples.html

The rest of this chapter is as follows. First, we provide a description and analysis of the prototype document collection that is used by VICOLEX. Next, we discuss a taxonomic framework for design of interaction with information. This taxonomy is the foundation upon which VICOLEX is designed. It helps us with a systematic analysis of VICOLEX and shows how using different interactions can support collection understanding. Afterwards, we analyze the different interactions in VICOLEX and discuss their utilities.

4.3.1 Description and Analysis of VICOLEX's Document Collection

Our prototype collection is comprised of 349 surrogate MARC records about Local History and Description of Ukraine from the Library of Congress Catalogue (described in detail in Buchel & Sedig, 2011). We will henceforth refer to this collection as LHUC (Local History of Ukraine Collection). LHUC's records belong to DK508 class in the LCC. From each record we have selected only the key ontological properties—that is, physical descriptions (illustrations, maps, height of the book, number of pages in the book, year of publication, place of publication – all of these attributes are recorded in MARC 300), languages (field 041), types of publication (serial or monograph, field 006), bibliographic notes (MARC 504), subjects (fields 650 and 651), titles (field 245), call numbers (field 050), and acquisition numbers (MARC 010). Locations found in the LCC were enhanced with gazetteer descriptions which include footprint information (latitude and longitude), names (main and variant), and population size. The purpose of these descriptions is twofold. First, they are required for mapping placenames on Google Maps. Second, they are intended to enhance understanding of georeferenced locations in LHUC (e.g., having population size allows us to filter out collections by small, large and medium-sized locations). Although LHUC seems simple to visualize, prior to visualizing it, we analyzed its structure, transitional processes, and other latent properties, relationships, and trends. We present some of this analysis next.

Structure. LHUC belongs to schedule DK508 which is a lower class in schedule D (History) and is comprised of smaller sub-collections, each of which is about a specific geographic location in Ukraine. LHUC is characterized by thematic cohesiveness and similarities in bibliographic descriptions. In addition, LHUC's documents are imbued with illustrative matter (e.g., illustrations, maps, portraits) which share among them such things as travel guides, encyclopaedias, directories, guidebooks, pictorial works, and tour guides. They hardly have any temporal properties and they serve one group of users: genealogy and history researchers. Altogether, the collection has 32 sub-collections, each of which being about a geographical location in Ukraine (e.g., Kiev, Lviv, Kharkiv, Odessa, and other cities and towns). The arrangement order within each sub-collection is alphabetical. Some of these are large (containing 100 or more records), and some are small (containing 1-3 records). Sub-collections inherit many properties of LHUC and are closely interrelated and interdependent. If a sub-collection is removed from or added to LHUC, its ontological properties are affected.

Transitional processes. LHUC, similar to other library collections, can be subject to numerous multidirectional transitional processes and changes which are not easy to discover in library catalogues or simple MBVs. However, results of statistical analyses and studies of other collections provide substantial evidence that transitional processes can be traced in ontological properties of collections (e.g., changes in subjects, languages, and document sizes).

Document sizes have changed over time. In early 1800s, nearly all books were printed in one of four formats or in half-sheet versions of those formats. At that time size was not only a physical characteristic, it carried information about the contents of a book. For instance, in English printing, quarto size was used for printing the Bible until 1800, and, in some European countries, duodecimo format was used for small devotional books during 17th and18th centuries (Gaskell, 1972). Also it appears that Russian books by authors who are considered less important are often printed in small or miniature formats. For instance, some books by Russian women writers were printed in small formats. Languages in collections are also subject to change. For example, in 1907, about 50 percent of the Chemical Abstracts were published in German (Heumann & Bernays, 1959). By 1937, this had been reduced to 15 percent, with 40 percent in English, and by 1959, about 80 percent were in English, with only 2 percent in German, demonstrating the shift from German to English as the principal language for chemistry publications. Subjects also change over time. The Library of Congress Subject Headings (LCSH) have undergone many syntactic and semantic changes. For instance, recent economic and usability aspects of pre-coordinated syntactic order in LCSH along with the rising keyword search popularity have caused many simplifications in subject headings (Cataloguing Policy and Support Office, 2007). In addition, the LCSH terminology is constantly affected by word meanings that mutate rapidly due to social and political upheavals, and scientific and technological developments (Taylor, 2000). Finally, genres and forms have gone through numerous changes as well. Early categories of forms/genres were treated as subjects in metadata records. They included such genres as encyclopaedias, biographies, and histories, as well as chemistry and religion. They have only recently begun to be treated as terms and phrases that designate specific kinds or genres of materials. Examples of newly-emerged genres are aerial photographs, French dictionaries, conversation and phrase books, and science fiction (Taylor, 2000). Despite all these transitional changes, such properties remain unchanged in metadata records and can be traced and found in old records. Making sense of all these transitions in collections with the library catalogues and simple MBVs is not an easy task. Such transitions are not immediately noticeable—neither in metadata records, nor in graphical representations that simply show the structure of collections. This is because such changes occur over some period of time and are very difficult to detect without the aid of proper interactive visualization tools.

4.3.2 Systematic Design Using a Taxonomic Interaction Framework

To decide in a systematic way what interactions VICOLEX should provide to users, we consulted the comprehensive taxonomy of interactions, EDIFICE (Epistemology and Design of human-InFormation InteraCtion in knowledgE activities), developed by Sedig & Parsons (Submitted), presented in Table 4.1. This framework characterizes epistemic action patterns using which users can interact with digital information representations to perform knowledge activities, such as sensemaking. This framework divides epistemic actions into two main categories: unipolar and bipolar. The unipolar actions are performed in one direction and do not have natural opposite actions. After committing a unipolar action, users can only reverse it by performing an undo action. The bipolar actions, on the other hand, have two opposite actions. Table 4.1 lists EDIFICE's actions and provides a brief characterization of each action. In this table, DIR signified digital information representation.

	Action	Characterization
Unipolar Actions	Annotating	augment DIRs with personal meta-information and coding schemes
	Arranging	change order of DIRs
	Assigning	bind property to DIRs (e.g., feature, meaning, function, value, or behavior)
	Cloning	create multiple identical copies of DIRs
	Comparing	determine degree of similarity or difference between DIRs
	Drilling	bring out, make available, and display interior, deep information in DIRs
	Filtering	show and/or hide a subset of DIRs' elements according to certain criteria
	Measuring	quantify properties of DIRs (e.g., area, length, mass, temperature, and speed)
	Navigating	move on, through, and/or around DIRs
	Scoping	dynamically work forwards and backwards to view compositional development and growth of DIRs, either temporally or spatially
	Searching	seek out the existence of or locate position of specific entities, relationships, or structures in DIRs
	Selecting	focus on or choose DIRs, either as an individual or as a group
	Transforming	change the geometric form of DIRs
	Translating	convert DIRs into alternative informationally- or conceptually-equivalent forms that require different degrees and kinds of cognitive processing
Bipolar Actions	Accelerating/ Decelerating	increase speed of movement of constituent components of DIRs, or oppositely, decrease their speed
	Animating/ Freezing	generate movement in constituent components of DIRs, or oppositely, stop their motion

	Collapsing/ Expanding	fold in or compact DIRs, or oppositely, fold them out or make them diffuse
	Composing/ Decomposing	bind DIRs together and create a singular entity, or oppositely, break whole entities up into separate, constituent components
	Gathering/ Discarding	gather DIRs into a collection, or oppositely, throw them away completely
	Inserting/ Removing	interject new information into DIRs, or oppositely, get rid of their unwanted or unnecessary portions
	Linking/ Unlinking	establish a relationship or association between DIRs, or oppositely, dissociate them and disconnect their relationships
	Storing/ Retrieving	put DIRs aside for later use, or oppositely, bring stored DIRs back into usage

Table 4. 1 Taxonomy of epistemic action patterns.

Notably, the above framework omits zooming, panning, and scrolling, the three staple interaction techniques for digital maps which are often referred to in the literature as interactions. The reason for this is that this taxonomy makes a distinction between interaction techniques and interactions. Interactions are abstract, conceptual patterns, while interaction techniques are more concrete instances of these abstractions. For example, zooming is an instance of the epistemic action of translating if it involves changing a representation from one form to another (i.e., semantic zooming) and the epistemic action of drilling if it involves geometric enlargement. The reason why we chose a framework that focuses on action patterns rather than techniques is because the number of techniques is already overwhelmingly large and designers do not use a coherent language when describing them. For this reason, the taxonomy provides us with a more robust vocabulary for understanding each interaction and its utility for performing knowledge activities.

Besides understanding each action, the taxonomy allows for a systematic analysis and design of interactions for different kinds of spaces in VICOLEX. For instance, while filtering, transforming, and measuring can help reveal the structure, properties, relationships, and transitions in a semantic space and measure distances between geographic objects, other interactions are geared more towards allowing users to appropriate the information space and turn it into a place that fosters understanding. Some of the proposed interactions can augment understanding of representations, especially such complex representations as maps, in which users have to utilize selective attention - a process of sampling visual information over time by selective perceptual acts that direct attention to a restricted region of the visual field.

4.3.3 Implemented Interactions in VICOLEX

VICOLEX implements several of the interactions in EDIFICE, specifically navigating, filtering, selecting, annotating, drilling, comparing, and gathering. In the rest of this section we discuss how these interactions can be integrated into a complex MBV and examine their role in supporting sensemaking activities such as collection understanding. Although the analysis here focuses on how the implemented interactions enhance and support understanding of the selected prototype collection LHUC, the way VICOLEX utilizes interactions for enhancing sensemaking can be found useful for many other collections from other subject domains.

Navigating. Navigating involves moving on, over, or through a representation, with the destination seldom pre-determined. It rarely modifies the representation itself and is useful for structural exploration and understanding of social affordances of places. The purpose of navigating is generally twofold: a) to enable users to learn how to get from point A to point B on a map; and b) to support the formation of cognitive maps (Sedig et al., 2005). As people navigate a space, they assimilate information into their own cognitive maps, which extends processing beyond walking through space to interpreting meaning and drawing important cues about implicit spatial positions and semantics (Dillon, 2000). VICOLEX supports formation of cognitive maps by making various spaces of LHUC salient. For example, VICOLEX highlights places that users visit the most as heat areas (shown as red circles in Figure 4.1). These heat spots are generated by continuous automatic annotation updates of log data of what has been visited and how often. The markers and the sidebar display affordances of the semantic space. They inform users of where to go, what to expect, and what other people do in these spaces.

In VICOLEX navigation in both the semantic space on the map and the semantic space in the sidebar are linked. In the sidebar, collections are ordered alphabetically so as to make navigation between geographic placenames much easier for users who do not know the location of placenames on the map. This order plays the role of routes in navigation; they show proximity of collections on a bookshelf. On the maps, collections have geospatial locations which facilitate understanding of geographic relationships and distances between them. Despite obvious virtues of both sidebar and map representations, it is not always easy to see their connection. To make this relation apparent, as users click on an item in the sidebar panel, VICOLEX changes the color of its related marker on the map and opens an information window (Figure 4.2). Alternatively, clicking on the marker highlights the related entry in the side panel. By walking from one item to another, users can see the proximity of collections on the bookshelf, and at the same time they can observe the proximity of locations and distances between locations on the map. Alphabetical order supplements navigation on maps with a linear order, which maps lack. The linear order helps users navigate from one marker to the next one. In other words, with tight coupling both types of navigation complement each other and extend the capability of each other. Alternatively, placenames in the VICOLEX sidebar can be ordered by collection size, which can help users generate different navigation paths.

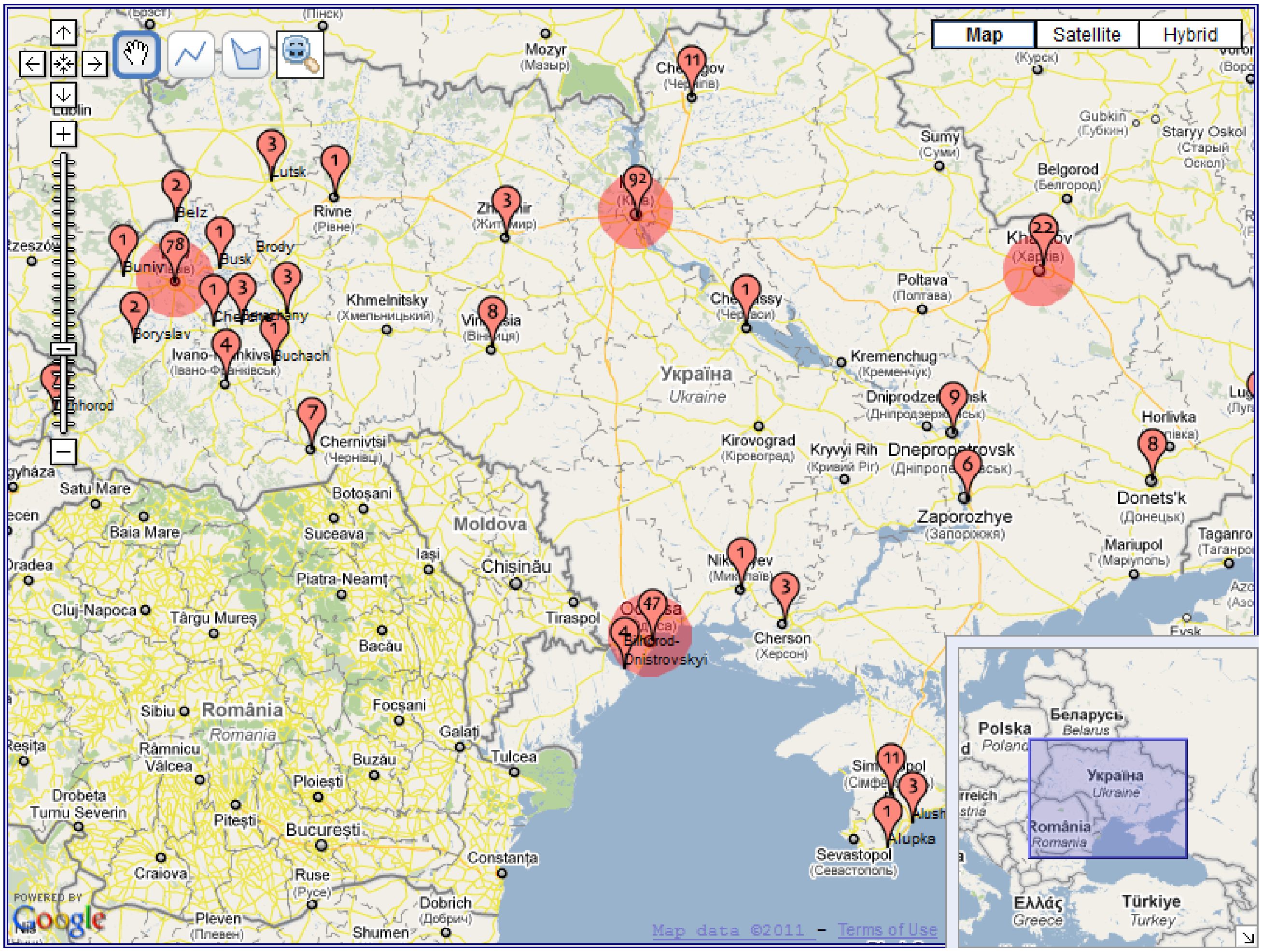


Figure 4. 1 Heat spots. Red markers on this map represent locations of collections and their size. Red-coloured circles around some locations show collections visited by users.

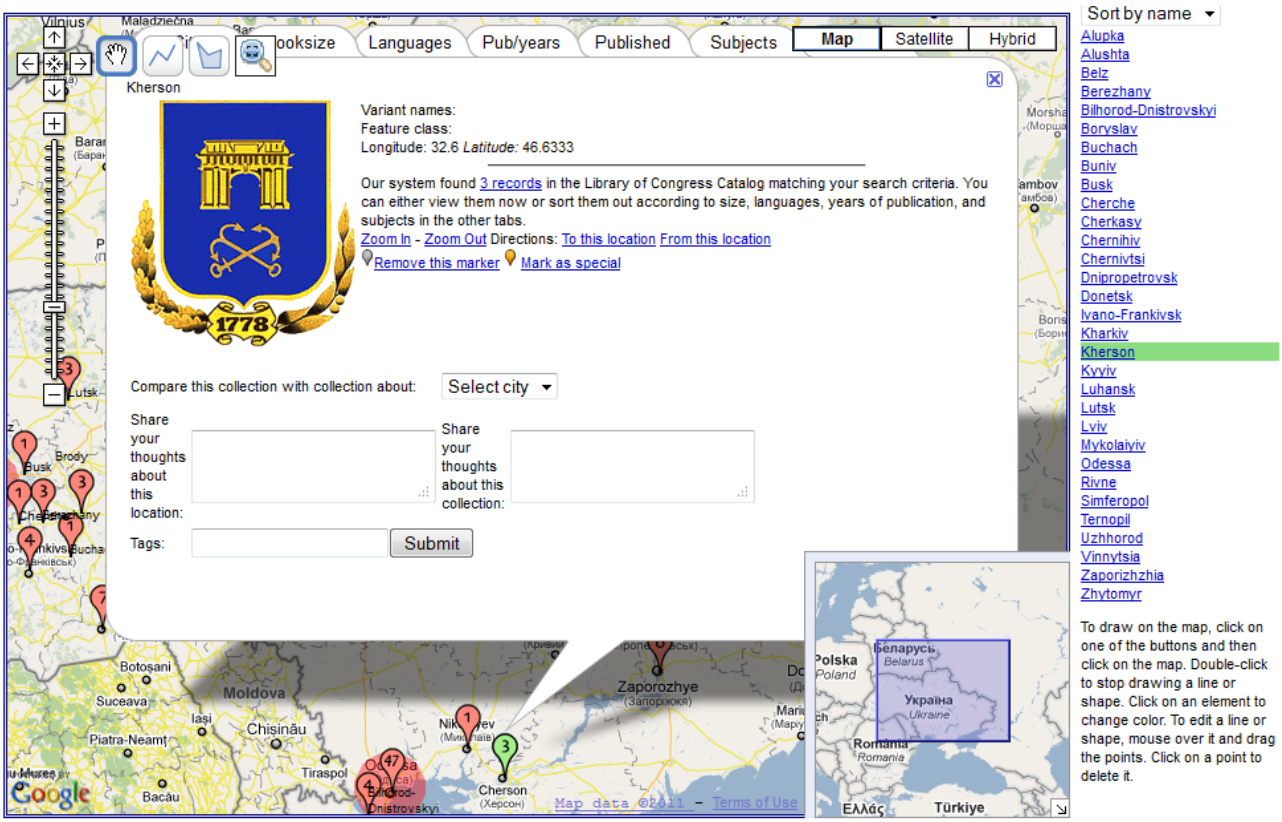


Figure 4. 2 Navigation in VICOLEX. This Figure shows how navigation in the sidebar is linked to navigation on the map in VICOLEX.

Drilling. Exploration of geographic locations in VICOLEX is further enhanced by drilling. Drilling refers to acting upon a representation in order to bring out, make available, and display its interior information. It is a mechanism for extracting hidden and perceptually-inaccessible information. While on many digital maps drilling of geographic locations is commonly done by automatic speed-dependent zooming (Harrower & Sheesley, 2005), VICOLEX augments automatic zooming with the discrete zooming/drilling technique that can be found inside each marker. The purpose of this technique is to eliminate excessive drilling that comes with automatic zooming in Google Maps. There is evidence that excessive drilling can cause frustration, reduce satisfaction, and affect task performance (Spool, Scanlon, Schroeder, R., & DeAngelo, 1999; User Interface Engineering, 2001). Discrete zooming allows users to rapidly leave the viewing area and enter the target scale with the best representation of the location. This is important because locations are represented at different scales and users do not know at what the best scale for the representation of a certain location is. With discrete zooming users can make discrete jumps to their target representations (Jog & Schneiderman, 1997). Discrete zooming-in allows users to make rapid adjustments to the scale without the need to move through all the map layers and without losing track of the target location. Discrete zooming-out allows users to go immediately back to their initial map layer. Such drilling is also intended to overcome the problem of imprecise automatic zooming in Google Maps that may cause users to lose focus of the target (Nivala, Brewster, & Sarjakoski, 2008).

Overall, the combination of navigating and drilling in VICOLEX supports the acquisition of three types of knowledge: (1) landmark knowledge about geographic locations, collections, and social cues; (2) route knowledge about collections and geographic locations; and (3) survey knowledge about semantic, geographic, and social spaces. As such, the externalized cues about various spaces are intended to support the development and formation of the users' internal cognitive maps of geographic locations, collections, relationships and orderings among them, and to provide a context to support the navigation processes of browsing, modeling, and interpreting locations, collections, and social cues (Spence, 1999; Liang & Sedig, 2010).

Linking. Despite being useful for forming cognitive maps of geographic spaces, navigating and drilling fail to support sensemaking at a deeper level. Exploration of the structure of collections in VICOLEX is facilitated by linking. Linking refers to acting upon two or more representations to establish a relationship between them. Linking extends navigation; this is because navigating involves steering across links. The importance of linking was a foundation for early work on hypermedia and knowledge organization. People think and learn through associations. Links define associations, and therefore help users gain a deeper understanding of the information, and learn the associations through navigating the links. This was the basic premise for Bush's paper "As We May Think" (Bush, 1945), Paul Otlet's vision about organizing knowledge (Rayward, 1994), and many other classification theories. In library and information science links are typically associated with explicit links specified between documents. However, this is not always beneficial to users. For example, long unstructured lists of links can cause cognitive overload and disorientation (Dalal, Quible, & Wyatt, 2000). To reduce the number of visited nodes and users' learning time, one of the techniques that some researchers (e.g., Yesilada, Bechhofer, & Horan, 2007) recommend is the use of link embellishments (e.g., descriptions, thumbnails, summaries, toolboxes, or linkboxes). VICOLEX, for example, embellishes links to documents in the tabbed information windows by providing additional graphical representations of ontological properties of collections (e.g., document sizes, languages, years of publication, subjects, places of publication, and collection properties)—see Figure 4.3. The advantage of this is that it reveals layers of hidden information about contexts of collections and geographic locations. This approach can aid users' orientation within and understanding of the collection structure as well as reduce the time required to learn about documents in the collection or the time required to find relevant documents. These additional representations can steer users' sensemaking activities by suggesting what new questions, properties, and relationships to explore. Linking in VICOLEX extends navigation and drilling by letting users inspect the various collection properties.

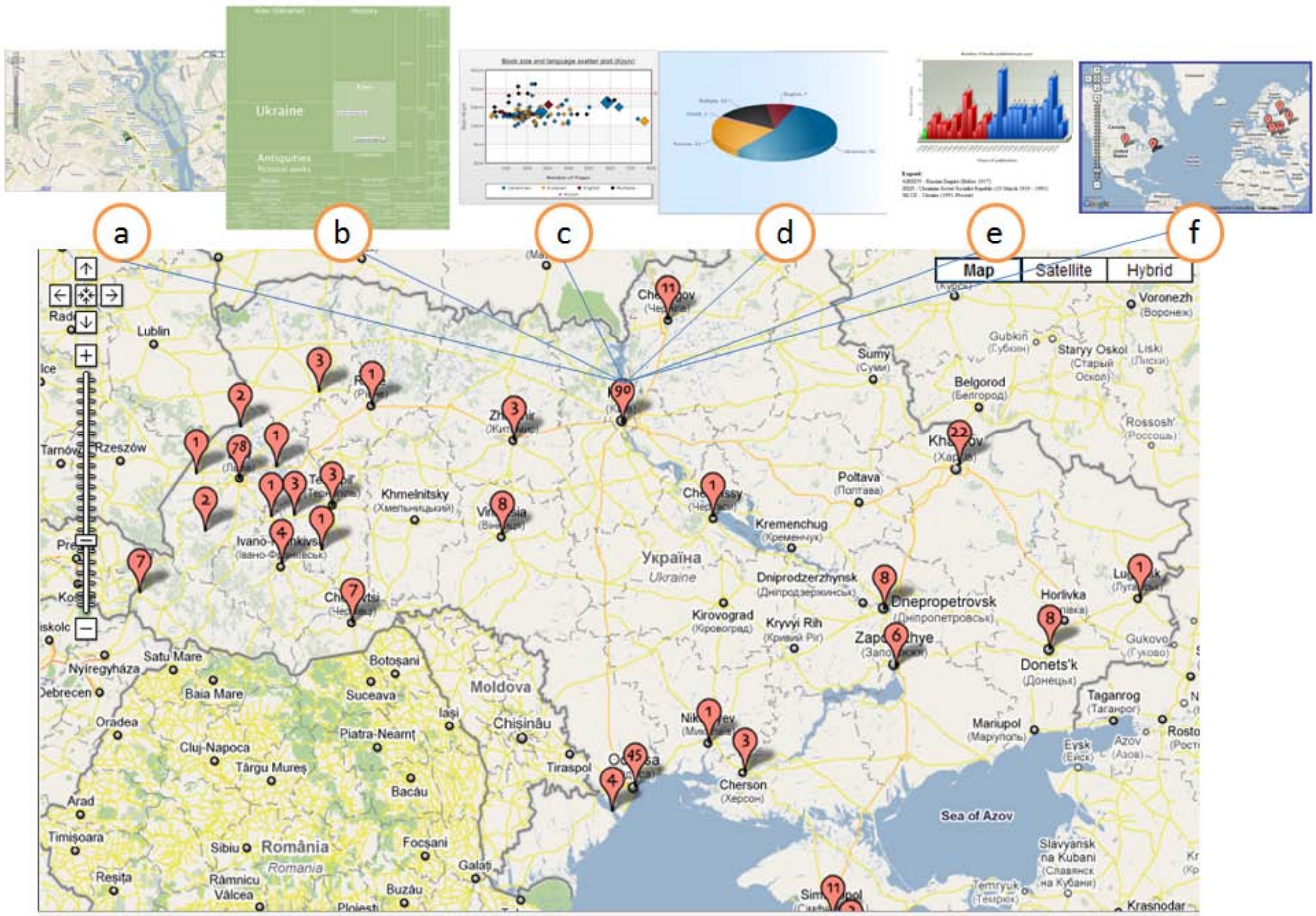


Figure 4. 3 An example of linking in VICOLEX.

Filtering. VICOLEX uses filtering to enhance collection understanding. Filtering refers to acting upon a digital map or its constituent representations to show and/or hide a subset of their items according to certain criteria. Figure 4.4 shows VICOLEX's map enhanced with the filter-based legend. These filters consist of property selectors and range selectors. The property selectors allow users to query the ontological properties of collections. These consist of five groups of checkboxes, one for each group of properties – that is, genres/formats, most frequently used subjects, physical properties (i.e., illustrations, maps, and other artifacts), languages, and types of geographic locations. The two range selectors (or sliders) enable users to specify the ranges of time related to acquisition and publication. Users can specify a range of values by setting a lower and upper limit or a specific value by setting both ends to the same value. The property and time selectors are linked to the map and the sidebar panel, where collections and documents that satisfy the current query are displayed (see Figure 4.4). These filters allow for narrowing of attention to relevant information, so that users can study individual documents and sets of documents to understand them better (Shneiderman, 2008). They also allow users to reduce the amount of visual clutter on the map, to have control over what objects they want to view, and to adjust the degree of detail and abstraction of documents. Inhibition of irrelevant information is critical for improving memory of relevant information and hence sensemaking (Cowan & Morey, 2006). Clutter reduction enables users to focus on spatio-temporal patterns and distribution and density patterns of properties. This in turn minimizes mistakes in property-oriented visual tasks (Luck & Hillyard, 1994). Filtering in VICOLEX, similar to filtering in some other visualization tools (e.g., dos Santos, 2004), reduces the complexity of high-dimensional data, gives users flexibility in selecting properties, and generally tends to be more effective because it generates a number of simple, easy-to-understand displays, each focused clearly on a particular aspect of the underlying information. For example, by setting the language to Russian (as shown in Figure 4.4) users can observe the distribution and numbers of Russian language books in this collection. This representation is very simple and easy to understand.

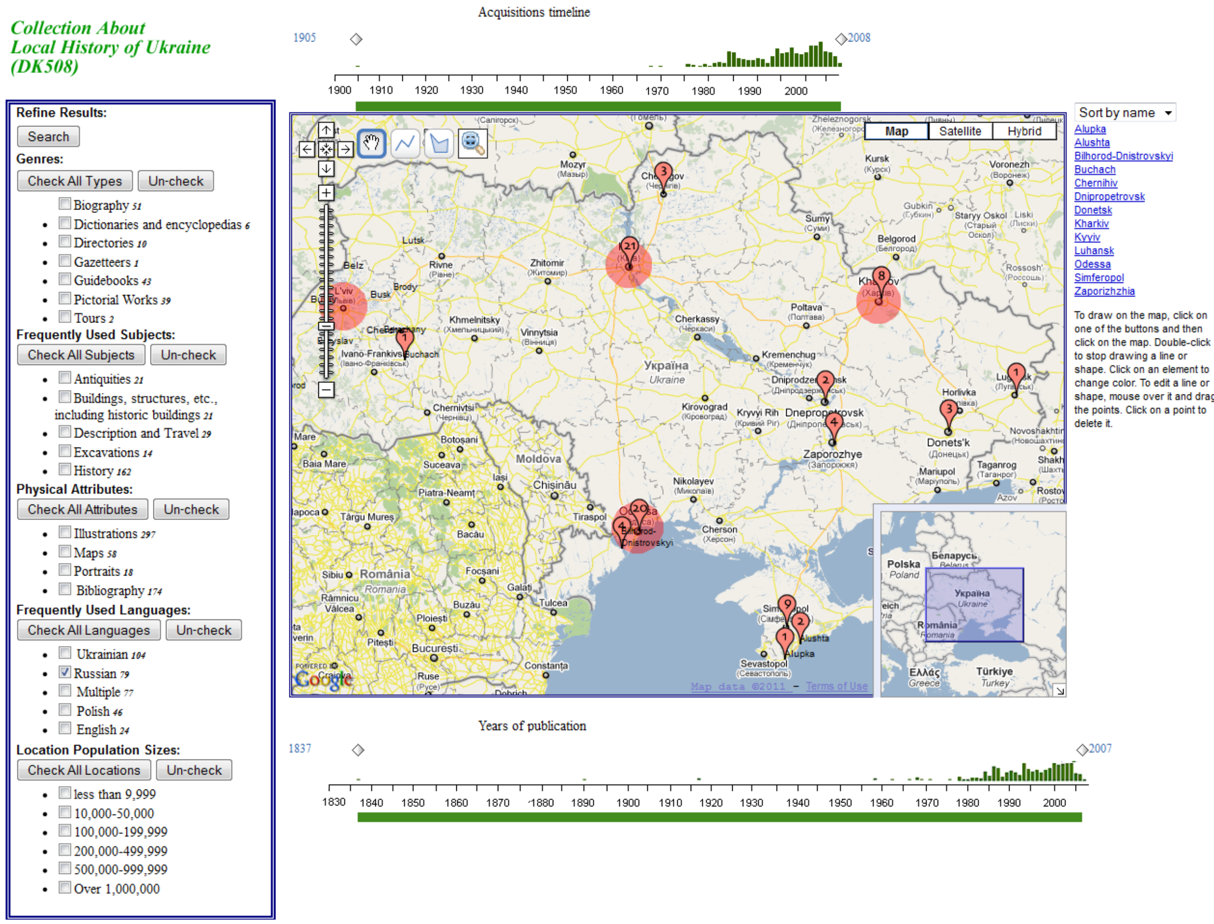


Figure 4. 4 An example of filtering by Russian language in VICOLEX.

Another filtering technique used in VICOLEX is spatial region filtering. This technique allows for focusing on certain regions on the map and at the same time displaying what geographic locations can be found within a specific LCC schedule. It is accomplished by means of region specifications, facilitated by geographic proximity of locations found in the LCC schedules. For example, our DK508 schedule contains documents only about one geographic area, namely, Ukraine. With spatial region filtering we are able to set the focus of the map to Ukraine and remove from the view all other locations which are not relevant to this collection. Such filtering has many advantages. It helps users understand spatial boundaries of the collection and restrict users' sensemaking only to a certain area. It also helps process illustrative properties like maps by facilitating better retrieval, reduction of the spontaneous classification errors, and better differentiation of regions (Rodhetbhai & Lewis, 2007; Brooks, 2007).

In addition to supporting understanding of collection properties on the map, filtering in VICOLEX also affects the representations of ontological properties of individual collections linked to markers. Because of filtering on the map, the representations of ontological properties in the collections become more malleable, flexible, reconstructable, prunable, and therefore more suitable to sensemaking. Consider an example of filtering representations of ontological properties as shown in Table 4.2. Column A in Table 4.2 includes representations of collection properties for the entire Lviv collection. This collection consists of 78 items. Column B represents properties of the subset of this collection which contains only items about *Description and Travel* and items with maps. After filtering, this sub-collection has 23 items. Comparison of representations in both columns reveals that representations in column B are more legible, less dense, and easier to understand. Such filtering allows completing tasks not at the level of objects, but properties. It makes properties much more salient as well as exposing, concealing, or transforming elements of a representation that possess certain characteristics or match certain criteria (Fast & Sedig, 2009). It also allows combining and excluding properties that are too difficult to understand. Overall, we see that different filtering techniques combine to support different aspects of collection understanding.

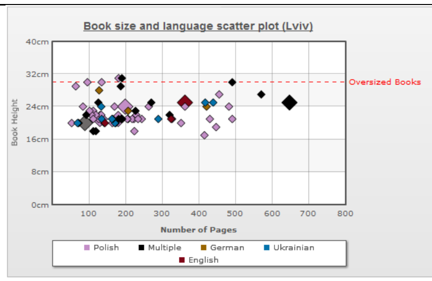
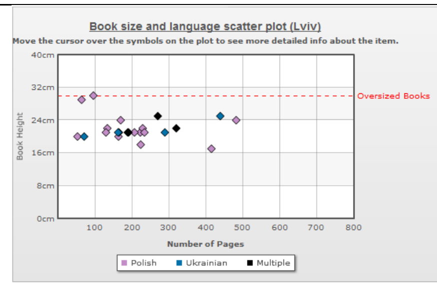
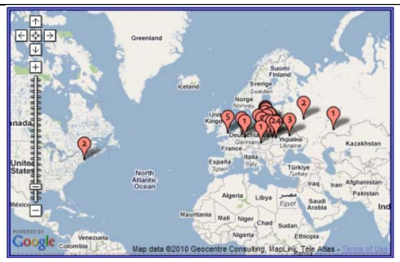
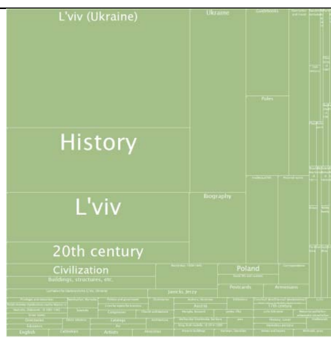
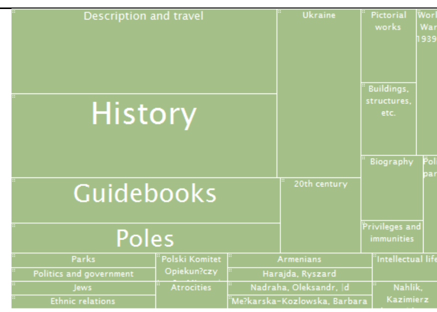
Properties	*A. Entire collection for Lviv city*	*B. Sub-collection for Lviv city after filtering*
# of items	78	23
Book sizes and languages		
Places of publication		
Subjects		

Table 4. 2 Filtering of representations of ontological properties in VICOLEX.

Comparing. Another interaction used in VICOLEX to enhance collection understanding is comparing. Comparing refers to acting upon two or more representations to determine their degree of similarity or difference, where similarity and difference can be in terms of proximity or distance between value, meaning, geometry, topology, and/or other properties. Generally speaking, comparisons aided by proper representations play an important role in visual reasoning tasks (Buchel & Sedig, 2011). In sensemaking, however, users often engage in more complicated comparisons involving more than one representation. VICOLEX supports such comparisons by arranging properties of collections side-by-side in a table. In this table, representations of properties can be compared side-by-side in rows. Such side-by-side comparisons are easier to accomplish than memory-based comparisons, because users can concurrently view the same aspects of different objects. Juxtaposing views facilitates visual verification of verisimilitude between ontological properties of collections that are hidden from view (Sahasrabudhe, West, Machiraju, & Janus, 1999). Juxtaposed views impose smaller demand on visual memory and simplify perception and internal computation by eliminating the need for mental alignment (Kastens, Liben, & Agrawal, 2008). Such views can bring out correlations or disparities and leverage perceptual capabilities to improve understanding of relations among views (Baldonado, Woodruff, & Kuchinsky, 2000).

Annotating. So far, we have not accounted for how users adapt spaces and turn them into places in which they "prepare" collections for understanding; in other words, we have not discussed place appropriating interactions. The ability to turn a space into a place is essential in sensemaking and understanding. Annotating can be regarded as a place appropriating interaction. Annotations are commonly thought of as notes made alongside text. According to Sedig and Parsons' taxonomy, annotating allows users to add personalized information to an MBV and create user metadata. Annotations help people create knowledge about locations by adding emotions, cultural information, blog entries, links, tags, and so on (Barricelli, Iacob, & Zhu, 2009; Bellucci, Malizia, Diaz, & Aedo, 2010; Simon, Sadilek, Korb, Baldauf, & Haslhofer, 2010; Krumm, 2007; Gazan, 2008; Haslhofer, et al., 2009). VICOLEX implements several annotation techniques: automated, structured, and free-text. Automated annotation is used to support the formation of cognitive maps as users move around the spaces and to enable them to retrace their walks if necessary. For this, VICOLEX marks users' footprints in the information space by changing the colour of visited markers, which act as electronic footprints to help users stay aware of what parts of the map have been visited. These footprints are added with minimal disruption to the flow of activity, placing the least cognitive demand on users (Marshall & Brush, 2004). VICOLEX tightly couples visited markers on the map to placenames in the sidebar by automatically annotating the latter (see Figure 4.5 showing green markers on the map and green highlights in the sidebar showing the user's path through the information space). This technique records user actions in two representations (i.e., the sidebar and the map) simultaneously. Figure 4.5 also shows gray and gold markers and highlights, where gray signifies that a marker has been deleted, and gold means that markers have been flagged as special. These annotations are intended to function as place markers, triggers or cues, to support remembering. Their purpose is to record users' interpretations (Marshall,1997; Kirsh, 2001). Annotative triggers or cues can guide attention: they designate triggers to ignore or to revisit in the future. It is noteworthy that the deleted markers are not completely removed from view, rather suppressed and marked as gray. This is intended to facilitate reasoning, since for better spatial reasoning both attended and unattended items should simultaneously be present in the visual field (Luck & Vogel, 1997). Changing the color of markers is an example of structured annotating. Structured annotating constrains what markers can be created, where they can be placed, or both. By constraining how annotations are created, disruption of the overarching activity is minimized. But at the same time the resulting annotations consistently provide users with semantic and mnemonic information about relevant, irrelevant, and visited collections. VICOLEX also supports free-text annotations. Such annotations are becoming increasingly popular in maps due to the recent dramatic growth in semi-structured, user-generated online content (Branavan, Chen, Eisenstein, & Barzilay, 2009). They have no fixed vocabulary, no explicit relationship between annotation key phrases, and no specific structure. Free-text annotations generate user-created metadata which capture user judgements, observations, opinions, problems, and solutions.

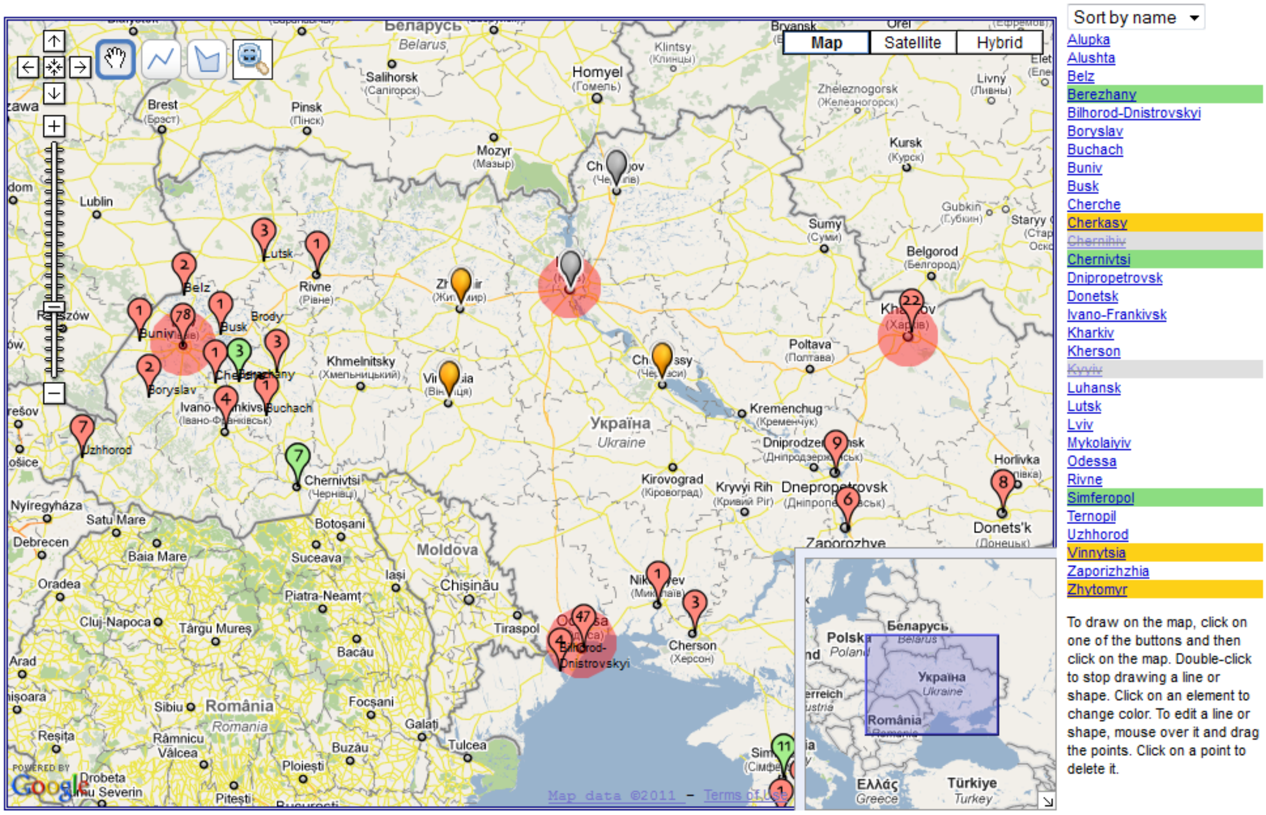


Figure 4. 5 Annotating in VICOLEX: green markers and highlights in the sidebar mean that collections have been visited; gold markers and highlights mean that collections have been marked as special; gray markers and highlights with crossed-out text mean that collec tions have been marked as irrelevant (discarded or suppressed).

Automated, structured, and free-text annotations in VICOLEX allow users to construct new places suitable for the activity at hand; that is, although users are unable to create their own representations from scratch, they can modify the existing map by augmenting it. This allows the offloading of cognitive load associated with keeping track of previous actions by externalizing them (Marshall, 1998). With annotations, users have indices to understand what is important in the document, collection, or location (Denoue & Vignollet, 2000). Such indices can allow generation of user-defined document clusters and classifications (ibid.), resulting in enhanced interpretation and understanding of collections (Srihari & Zhang, 2000).

Selecting. Another appropriating interaction is selecting. Selecting refers to acting upon representations to focus on or choose them, either individually or as a group. When applied to a set of representations, selecting can group and cluster them together. Currently the predominant selecting technique in MBVs is selection by clicking on a marker. Other techniques such as free-form selections (e.g., Lasso), bounding boxes, disjoint selection regions, circles of inclusion/exclusion, and multi-selections which allow selecting groups of markers are not frequently present in MBVs (e.g., Mizobuchi & Yasumura, 2004; Hinckley, Guimbretiere, Agrawala, Apitz, & Chen, 2006). But allowing users to select a group graphically is critical for minimizing cognitive demand, because with such a selection people do not have to think how to formulate a query in order to combine spatially distributed objects (Brown, 1998). This is especially important for geographic locations which are difficult to describe by words. Moreover, a group selection mechanism can streamline other interactions by removing the necessity to explicitly group and ungroup objects, potentially improving the cognitive and physical workflow of such interactions (Hinckley, Guimbretiere, Agrawala, Apitz, & Chen, 2006). Some empirical studies also show that when users are provided with the capability to use more flexible selection techniques (e.g., Lasso selection), they prefer them to click selections (Reilly, Welsman-Dinelle, Bate, & Inkpen, 2005).

To select groups of collections from areas of interest, VICOLEX uses a bounding box technique, traditionally used in map libraries for searching, first envisioned by Pruett (1986). Since its initial conception a number of map libraries have implemented bounding boxes in their MBVs. But as the second generation digital maps are becoming more mashable and it becomes easier to graphically represent collections on maps with markers and footprints, the graphical search technique is becoming obsolete (because users can see what is available). In VICOLEX, however, the bounding box is used for selection of collections that are already represented on the map (see Figure 4.6). For example, the mouse movements, clicks and releases required to specify a bounding box together define a focus area (i.e., a *hot spot*) on the map. Selecting then occurs by enclosing markers within a bounding box. This selection can be performed either on an entire collection or on a filtered collection. For example, a user can make visible only books about biographies and select only those from the right-bank Ukraine using the bounding box. Elements that are filtered, and hence invisible, cannot be selected with a bounding box. It means that these interactions enable users to define collections in their own way: collections and sub-collections no longer have to be fixed; they can be combined. Furthermore, once collections are selected, they can be acted upon with other interactions. For example, the selected collections are represented in a table while their properties are grouped together and shown on graphs and charts similar to the ones that are linked to markers (i.e., scatter plots, pie-charts, Kohonen maps, and so on). This feature is particularly useful when users need to think of and mentally manipulate a group of elements as one entity (Sedig & Sumner, 2006). Groupings can be useful for answering the following questions: a) what part of Ukraine collections is older (East or West)? b) Is there a difference in languages in collections about small locations versus large locations? c) Is there a difference in subjects in collections about West and East? The bounding box technique is not the only technique that can be used to specify selections on maps. Google Maps Geometry Controls allow drawing various regular or irregular polygons which help with more precise selections.

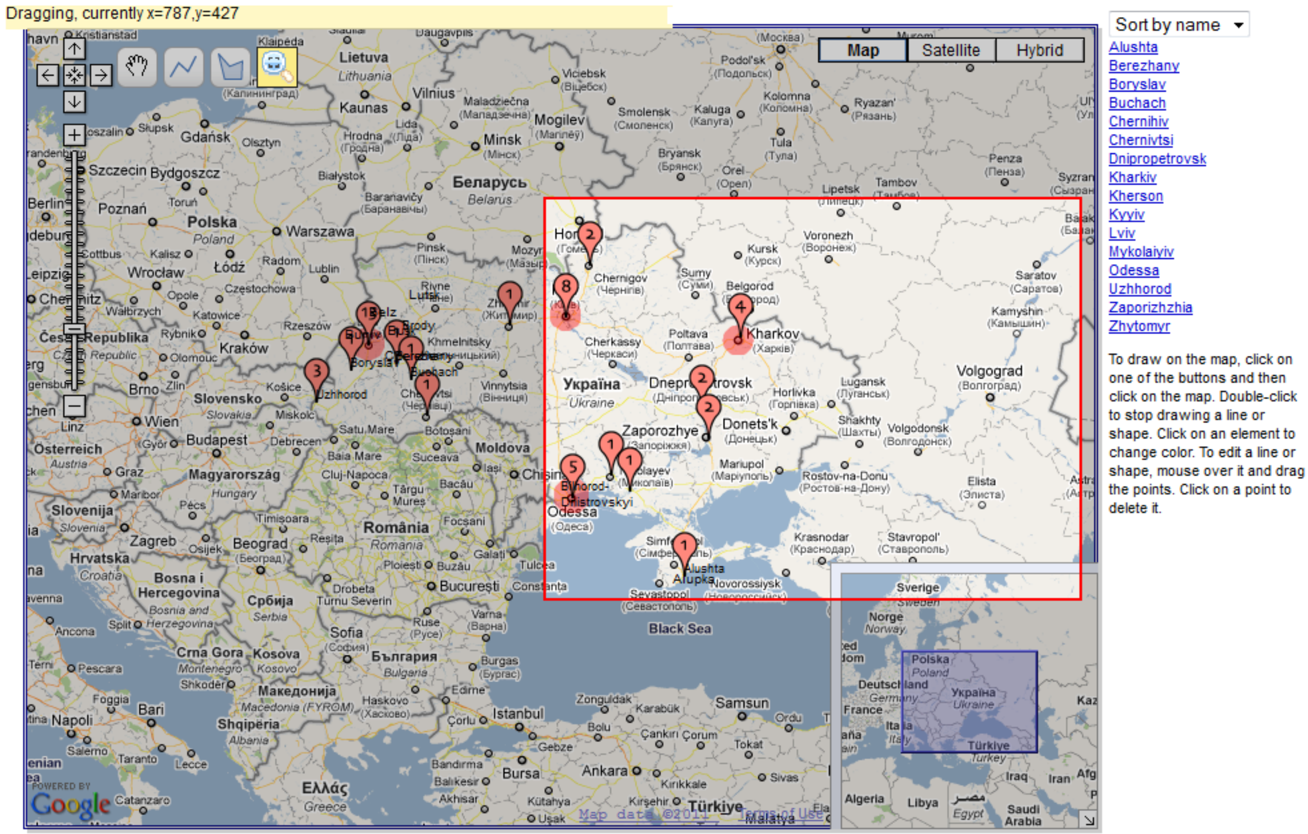


Figure 4. 6 Bounding Box selection in VICOLEX.

Gathering. Gathering on-line materials is one of the central tasks of users (Shipman, Marshall, & LeMere, 1999). Gathering refers to acting upon representations to place them into a container. On the one hand, gathering involves selecting and processing the collections or documents, as well as planning and replanning as some plans fail or new goals arise. On the other hand, information gathering can be viewed as an intermediate step in a decision making process that helps users organize their activity (Zilberstein & Lesser, 1996). As an organizing activity, gathering is associated with locating, retrieving, and integrating information from large numbers of distributed and heterogeneous documents and collections (Knoblock, 1995). Integration in the context of collection understanding is about creating representational structures from collections (i.e., structures from episodes as explained earlier). While integrating information, users rely on unstructured notes about identified evidence, important queries, and key questions that need to be addressed, as well as alterations of existing representations by adding new elements and relationships (Gotz, Zhou, & Wen, 2006). Gathering has many benefits for users. Gathering information can facilitate hypothesis testing and inductive reasoning by allowing users to focus on different aspects of information and help reduce the uncertainty regarding the value of some random variables in the users' decision models (Qu & Furnas, 2005). For example, it can reduce uncertainty regarding relevancy of collections for a task at hand. When gathering is not facilitated by the system, users need to resort to other tools for structuring episodes such as email or printouts (Bondarenko & Janssen, 2005).

Gathering is inherently spatial, implying a working space (or place) where users can place documents to conjoin, negate, disjoin, or specify relationships among them. When users modify their strategies or the structure of their spaces, they maximize their rate of gaining valuable information (Pirolli & Card, 1999). Commonly, in software applications such spaces are facilitated by concept mapping or mind mapping tools. VICOLEX takes a different approach and utilizes geographic space as a place for gathering information. Although the shape of the geographic space is not necessarily similar to the geography of the working space, there are many techniques that allow overcoming the idiosyncrasies of geographic and working spaces. Figure 4.7, for example, shows how all markers in the "working space" in VICOLEX are divided into three large episodes enclosed in polygons of different colors. Furthermore, by annotating users can assign meaning to each of these episodes. And by linking similar collections by lines, they can assign meaning to relationships, where width and color can encode types of relationships. Enabling users to assign meaning to relationships is critical, since this is an important component of relevance assessment in information retrieval (e.g., see Brooks, 1995).

Overlaying working space on the geographic space is not uncommon. The Toucan Navigator application (Schafer, Ganoe, Xiao, Coch, & Carroll, 2005), for example, uses a geographic map as a space for personal and collaborative activities. But the novelty of VICOLEX's approach is in merging geographic space with semantic, social, and working spaces. Such an approach has many advantages. It preserves collections (geographic locations and relationships among them as they exist in library catalogues) and gives users the ability to add their own interpretations of collections by annotating markers and episodes. It also helps users in exploring physical properties of episodes. For example, VICOLEX can calculate the size of the geographic area enclosed in an episode. Also, when users specify similarity relationships between collections, VICOLEX can inform them of geographic distances between locations and their directions. Knowing distances helps users get a better sense of space. Users often communicate and understand space by translating distances to travel time (Hill, 2006). For example, they often describe distances as 4-hour drive or 15-minute walk. This allows us to assume that information about distances between locations may help users estimate travel time between locations about which libraries have collections. Although distances cannot tell much about road conditions, or the preferred ways of commuting in other countries, they are still useful because they may stimulate users to ask further questions about collections and locations (e.g., why semantically-similar collections are separated by geographic distance, or why semantically different collections are located close to each other?), and consequently generate hypotheses.

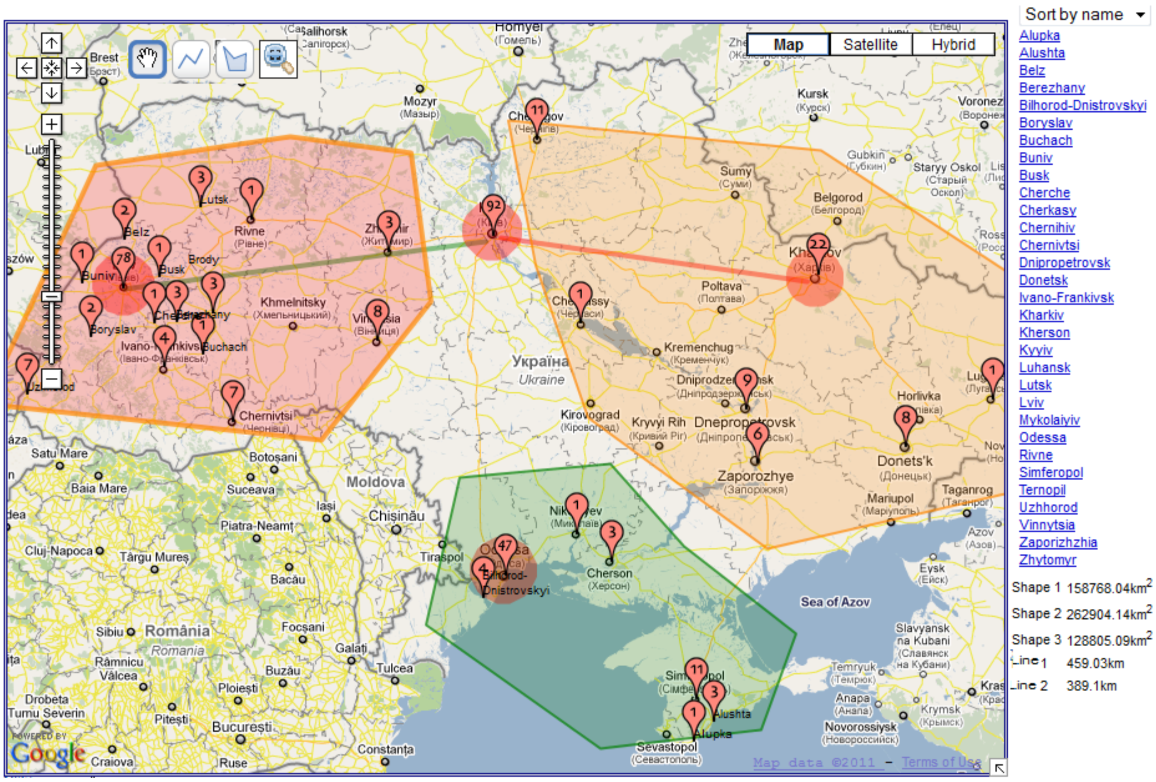


Figure 4. 7 Example of gathering. Here markers are grouped in polygons of different colors, and similar collections are connected by lines.

4.3.4 Combining Interactions to Understand Collections

Interactions in VICOLEX allowed one of the authors who can be considered an expert user of LHUC to make several interesting observations about transitional processes and properties of collections and locations. Specifically, the investigator's goal was to identify transitions, trends, patterns, and hypothesis related to LHUC and locations that it represents. This section describes the procedures and outcomes of this task.

The investigator started with an exploratory browsing of sub-collections on the map, investigating collection properties, and drilling into the larger scale map layers to see what the locations are about. The goal of this exploration was to make observations, to notice trends, patterns, and to generate hypotheses about patterns or properties of collections and locations. The linking and navigating interactions in the exploratory task allowed the researcher to notice that trends and patterns in the collection have some similarity to demographic data in locations, and that some of the trends and patterns are related to political and economic events in Ukraine. For example, many locations have spikes in publishing after 1991. The spikes can be explained by the collapse of the Soviet Union and the switch to the market economy in Ukraine. Other linked representations allowed generating hypothesis about transitions in languages, subjects, and places of publication.

With regards to understanding locations, the investigator noticed that many Ukrainian cities like many other cities in Europe are located on rivers or small streams. This observation was not possible to make from the main map representation, because the main map shows only the Dnieper, the largest river in Ukraine. Other streams and rivers are smaller and are not shown on the main map due to scale constraints. The relationships between rivers and locations became more apparent with drilling interaction which allowed the researcher to reach the GM layers of larger scale. To remember which locations were close to rivers, the researcher used structured annotation. All locations with rivers were marked yellow (gold), and those that did not have any rivers were left green. The map with these custom annotations is shown in Figure 4.8. Locations with rivers are shown marked with gold balloons, locations without rivers are shown in green, and one location is shown in gray. The location in gray is Lviv. The reason why it is marked with a special colour is because GM show that rivers in Lviv end before the suburbs. It looked strange. The researcher consulted some other sources and found that Lviv is built on two rivers which are hidden under the ground (http://www.river-cities.net/pages/cities/Lviv). It was an exciting finding, a serendipitous discovery which was not prominent in the visualization before the interaction. This example demonstrates how drilling and annotating interactions can enhance users' understanding of locations and foster further exploration and investigation in other sources. Moreover, not only these interactions can facilitate looking at individual locations, but also making generalizations about multiple locations in a reasonably small amount of time.

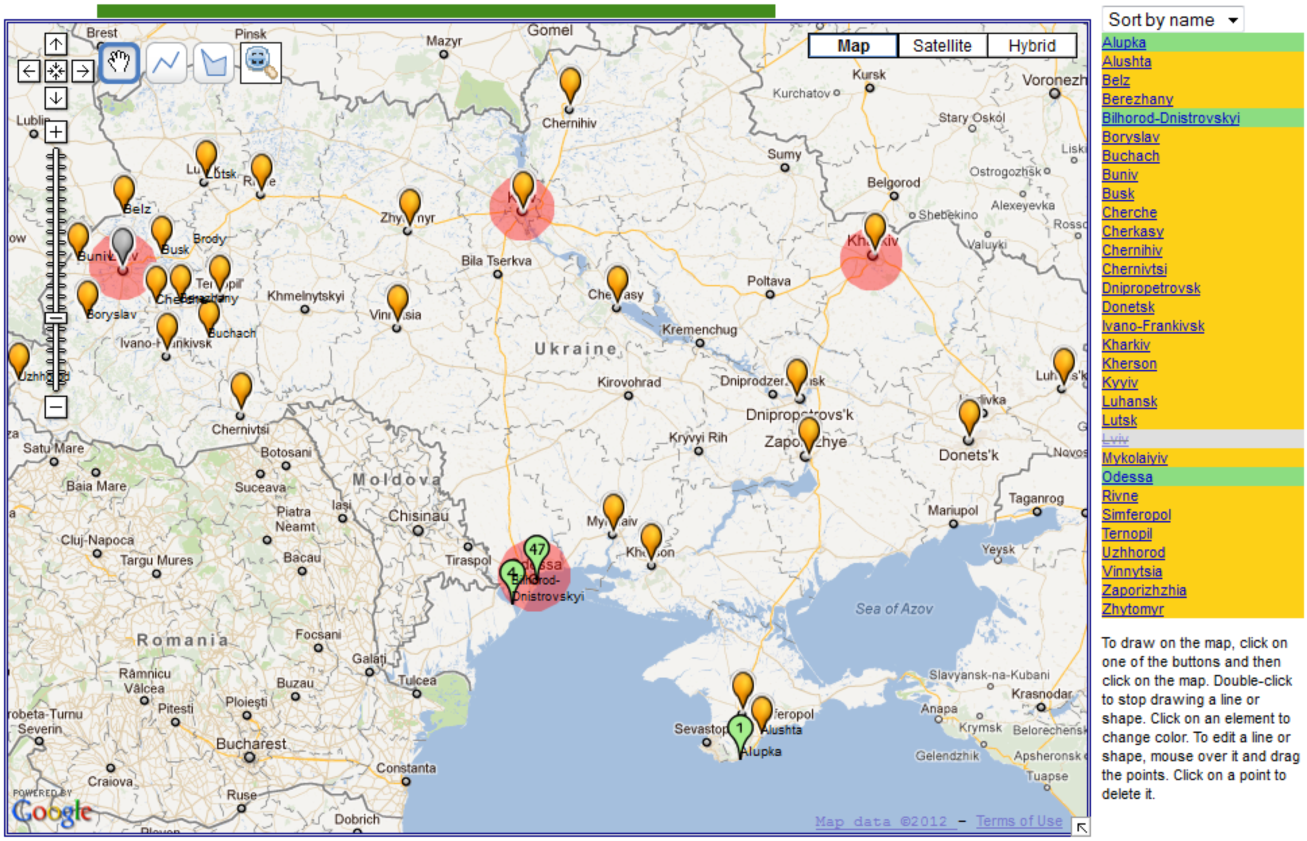
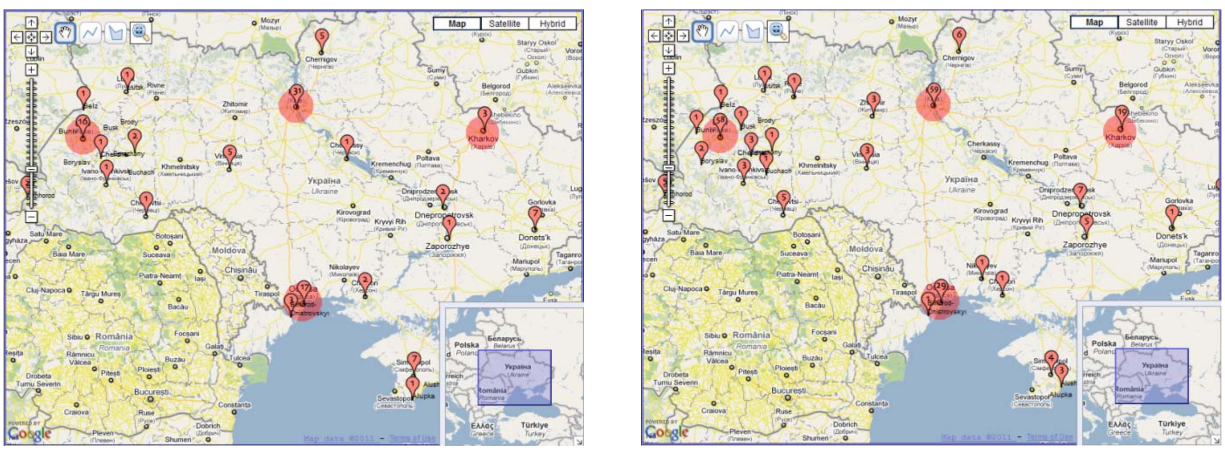


Figure 4. 8 Exploring locations to find which locations are located on rivers. Gold markers show locations on rivers or small streams; green markers show locations without rivers; and gray marker shows Lviv that has underground rivers.

In the future, the large scale layers in VICOLEX which are hidden beneath the main map can be enhanced with social media layers such as Wikipedia articles, YouTube videos, and Panoramio or Flickr images. While linking all these layers to the main map can make the visualization crowded, linking them to the large scale maps and allowing users to access these maps with drilling can enhance users' understanding of locations.

After exploring the collection, the researcher experimented with filtering. The collection was filtered by individual properties and in combination with other properties. Combined filtering was used for investigating temporal aspects of other ontological properties (Genres, Subjects, Physical Attributes, Languages, and Population Sizes of Locations). More specifically, the investigator looked at shapes, and quantitative and qualitative transitions in each of the above properties during 1917-1990 and 1991[8]-2007 periods. In addition, using selecting and linking interactions, the transitions were investigated both in individual locations and major socio-economic regions of Ukraine (East, West, and Crimea).

The outcomes of filtering can be classified with regard to quantitative transitions, shapes transformations, and geographic distribution changes. With regard to quantitative transitions, the investigator found that the larger half of the entire collection was published after 1991 (109 books were published in the period between 1917 and 1990; and 225 books were published after 1991). This is evident from the two map representations filtered by the years of publication: before 1990 and after 1991 (Figure 4.9). The comparison of the representations in Figure 4.9 reveals that there are more markers in Figure 4.9.b than in Figure 4.9.a, and the numbers of documents linked to the large cities are much higher in Figure 4.9.b than in Figure 4.9.a.



a) b)

Figure 4. 9 Collections pre- and post-Soviet era (respectively, a and b).

Another quantitative transition was observed about books containing maps. In particular, the investigator found that only 7 out of 57 map-containing books were published before 1991 (Figure 4.10.a and 4.10.b). Moreover, this quantitative transition is coupled with the transformation of the geographic distribution of these books. While 7 books with maps published during the Soviet-era

8 The landmark year when Ukraine became independent.

Ukraine were only about large cities (Lviv, Kyyiv, and Odessa), the remaining 50 books published after 1991 were about both large and small locations.

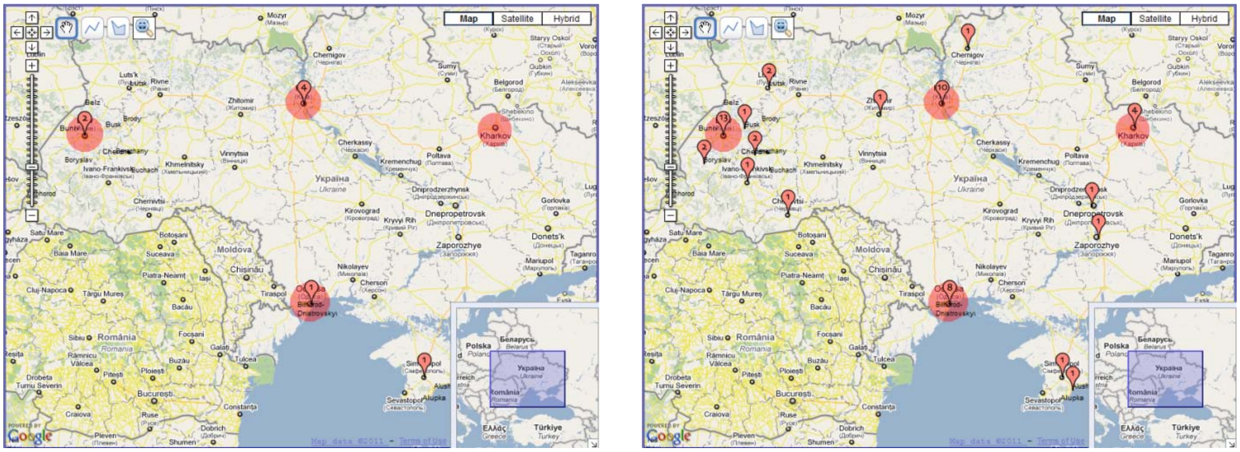


Figure 4. 10 Distribution of books with maps: a) through 1990; b) after 1991.

Quantitative transformations were found in languages, too. For example, filtering by time and languages revealed that books in Polish about Ukraine were almost non-existent before 1981 (see maps of publications in Polish before 1980 in Figure 4.11.a and after 1981 in Figure 4.11.b). But beginning with 1981 the number of publications in Polish increased significantly especially about Lviv (40 items). This can probably be explained by the fact that Lviv was part of Poland until 1939.

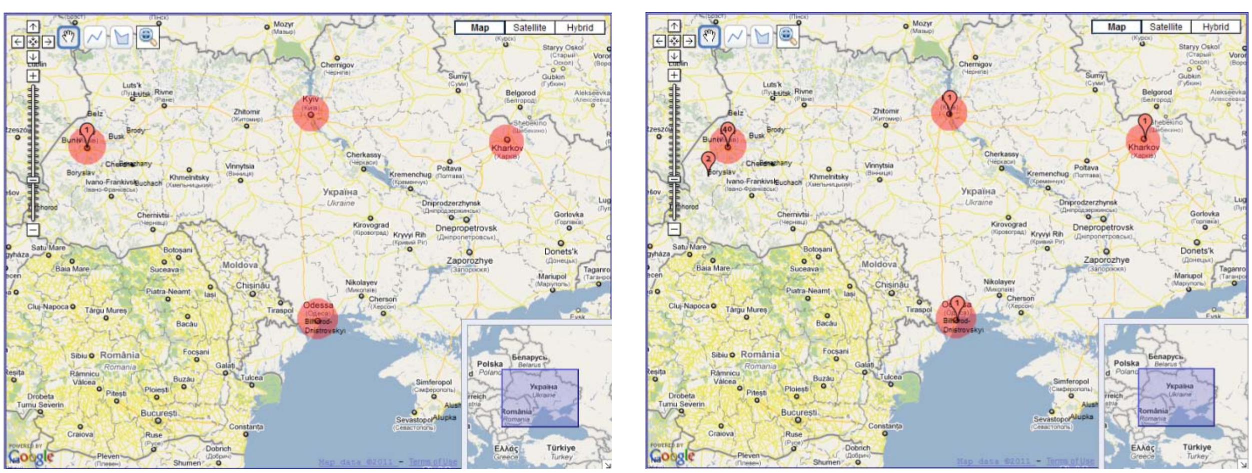
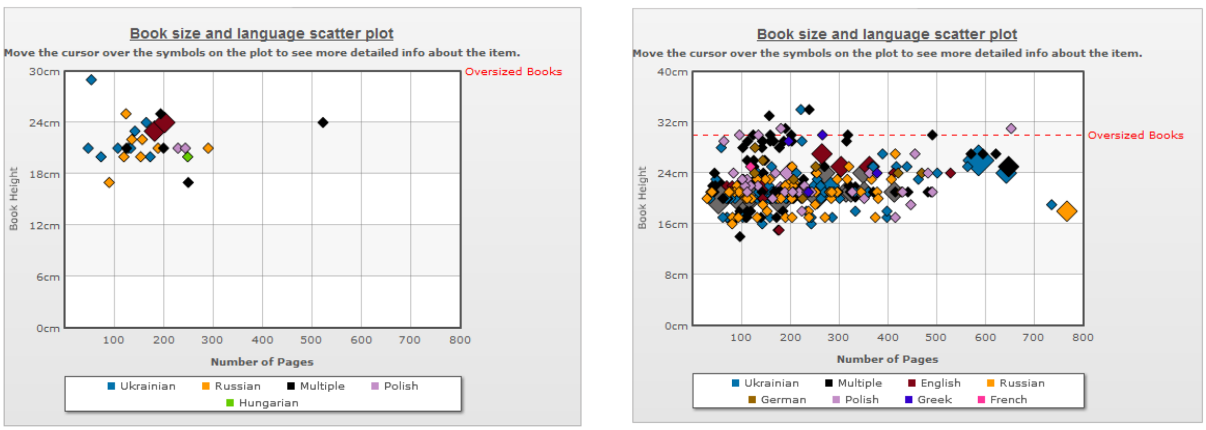


Figure 4. 11 Distribution of Polish language books: a) before 1980; and b) after 1981.

With regards to shape transformations, an interesting observation was made about a difference in book formats after the collection was filtered by Location Population Sizes and re-represented on a scatter plot by means of the selecting interaction. The resulting representations are demonstrated in Figure 4.12. The scatter plot in Figure 4.12 shows book sizes in the sub-collections about locations with population sizes less than 200,000 (a), and in the sub-collections about locations with population sizes greater than 200,000 (b). These two figures suggest that positive correlation between book sizes and location sizes might be possible because documents about smaller locations have fewer pages and are smaller in height than documents about larger locations.



a) b)

Figure 4. 12 Book sizes of collections about small and large locations: a) book sizes in the sub-collections about locations with population less than 200,000; b) book sizes in the sub-collections about locations with population larger than 200,000.

As to geographic distributions, they can be observed both in conjunction with quantitative changes and in isolation. Earlier in this section, we gave an example where the geographic distribution complements the quantitative change. Here is an example where geographic distribution has its own significance. For example, the researcher found that with a few exceptions Russian-language books are distributed more in the ethnically-Russian territory than in the ethnically-Ukrainian territory (see Figure 4.13, where ethnically Russian territory is highlighted).

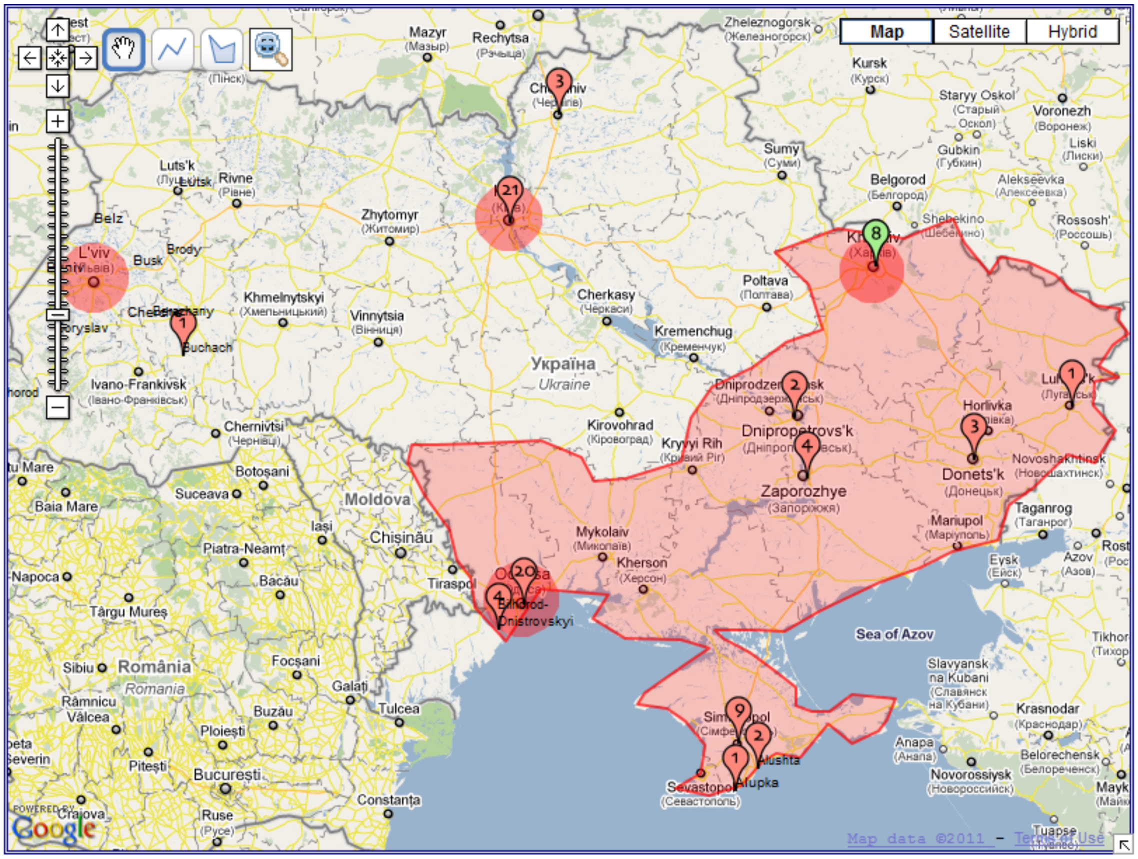


Figure 4. 13 Distribution of books in Russian. The "ethnically-Russian" is highlighted in red.

To validate the assumption about languages, the researcher used the GeometryControls to draw a layer right on top of the map visualizing library collections (Figure 4.13). This layer allowed the researcher to see better the spatiality of Russian collections with regards to the Russian-speaking regions in Ukraine. Although three locations lie outside the boundary of the Russian speaking regions, the researcher thought that some of them were accidental outliers, but one (Kiev) can also be considered a part of Russian-speaking community. In general, the layer aided the researcher to make a generalization about the distribution of Russian collections. VICOLEX also showed the numerical value of the area of the Russian speaking territory in Ukraine – a little more than 240,000 km^2 — which when translated to geospatial concepts of North America is equivalent to a quarter of Ontario's territory.

In this section we described trends, transitions, patterns, and observations which the expert user was able to notice in the prototype collection and locations by taking full advantage of interactions and representations in VICOLEX. The findings of the expert user demonstrate that interactions may enhance users' understanding about collections, their properties, distributions of properties, and properties of locations. While multi-scale maps like GM can help users gain deeper understanding of landforms, landscapes, areas, distances, and navigational routes in locations, other interactions such as annotating, selecting, and gathering help them capture their observations, generalize them, and make sense of them. Furthermore, findings described in this paper are not finite. Besides the afore-described findings, other users may find many other trends and facts that will help them generate new hypothesis and generalizations about collections. In this respect, we can speculate that the support for sensemaking in VICOLEX is open-ended.

4.4 Conclusions and Future Work

Throughout this paper, the goal has been to demonstrate analytically how interactions can reduce users' cognitive load and support their sensemaking activities. At first glance, any one of the interactions in isolation may seem insignificant. However, when analyzed and combined together, they can significantly reduce the overall efforts of users and may significantly expedite the time necessary for completion of sensemaking activities, which are typically time-intensive. Interactions facilitate these activities incrementally, one interaction at a time. Although with regard to VICOLEX we have yet to verify our argument empirically, based on evidence from other research (see, for example, Tudoreanu, 2003) and our own exploration presented in this paper, it seems highly plausible that augmenting MBVs with interactions can translate into improved support for users in their sensemaking activities.

Using VICOLEX, we have explained that navigating and drilling interactions can facilitate exploration of spaces; linking, filtering, and comparing interactions can facilitate understanding of collections, their properties, and transitional properties; and annotating, selecting, and gathering interactions can help users appropriate spaces and adapt them to their own activities. Besides interactions explained in this paper, there are many other interactions presented in the Sedig and Parson's framework that need to be investigated to determine how they can be implemented to enhance sensemaking activities in MBVs. This is an important direction of our future work.

In particular, currently VICOLEX does not provide adequate support for dealing with the multiple dynamically-generated representations which display multidirectional transitional processes. The difficulty with dealing with continuously changing information is that users need to identify and relate both spatially-separated as well as temporally-separated components of an MBV (Lowe, 1999; 2008). Moreover, in VICOLEX users have to relate spatio-temporal components to hidden layers linked to markers on the map. This presents the risk of excessive perceptual and cognitive demands made by the dynamic information that users need to process. Non-stable, transient information may impose a higher cognitive load on the users (Hegarty, 2004), because information about changes has to be kept in their working memory to be successfully integrated into a coherent mental model of the depicted subject matter. In addition, spatially-distributed representations may impede comparisons and other reasoning activities. Rensink et al. (1997) demonstrated that observers have great difficulty noticing even large changes between two representations when intermediary images are shown between scenes. Determining how to provide support for making sense of multidirectional transitional processes in MBVs is another line of future investigation and research.

Significance. The research and ideas discussed in this paper not only are significant for understanding and making sense of document collections, but also can play a significant role in the design of tools and interfaces that help people explore any kind of structured information with geospatial properties. For example, when trying to make sense of health data to develop public health policy and strategies, aggregating medical records by regions and using interactive map-based visualizations to explore them can help public health managers understand people's habits, demographics (age, occupation, health insurance), spread of diseases, geographic distribution of treatments and symptoms, and how children grow and develop in different geographic locations. This research can potentially be applied to visualization tools and information interfaces that are intended to support activities such as making sense of health records, making decisions involving real estate listings, understanding business and geo-economic information, and exploring natural and social phenomena (e.g., electoral votes, migrations, spread of diseases, political conflicts, and social networks).

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Chapter 5: Can Additional Representations in Map-based Visualizations Enhance Sensemaking Activities Such as Collection Understanding?[1]

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Abstract

This paper reports the results of an evaluation of a map-based visualization prototype VIsual COLlection EXplorer (VICOLEX) designed for facilitating collection understanding. In VICOLEX, collection understanding is supported by graphical representations of ontological properties of collections (e.g., scatter plots, pie charts, histograms, Kohonen maps, embedded maps, and tag clouds) and interactions with them (e.g., linking, navigating, selecting, probing, resizing, and some other). The study focused mainly on the role of representations in facilitating collection understanding. The researchers recruited 14 volunteers (1 for a pilot study and 13 for the actual study). The methodology of the study included a think aloud protocol, a semi-structured interview, and a survey. Although the findings of the study cannot be generalized beyond the techniques and the topic they examined, they suggest that additional representations can improve understanding of georeferenced collections.

5.1 Introduction

This paper describes an evaluation of VICOLEX, a visualization prototype designed for supporting sensemaking activities such as collection understanding. In particular, the study investigates how well the design of VICOLEX (particularly representations used in the tool) can help users understand and build a good mental model of a georeferenced document collection. Such a mental model is measured in inferences, discoveries, reasoning statements, and other outcomes of understanding.

In VICOLEX, collection understanding is supported by graphical representations of and interactions with ontological properties of collections. Examples of representations can be scatter plots, pie charts, histograms, Kohonen maps (KMs), embedded maps, and tag clouds. Each of these forms of representation represents a different kind of ontological property (e.g., scatter plots show book sizes; pie charts show variety of languages in documents, and so on). Understanding is facilitated by the capability of representations to communicate the encoded properties and to facilitate low-level visual tasks on representations. It is through such tasks, that users gain insight about underlying ontological properties and, ultimately, meta-knowledge about collections.

Moreover, since representations are graphical in nature, we may assume that such representations can be understood not only by expert users but also by novice users, who may neither have familiarity with the collection nor the ability to read titles in foreign languages. If this is true, representations may enhance access to information in collections which was previously inaccessible to many users, especially information in foreign language collections.

Our evaluation study poses the following research questions:

1. Can the proposed representations help novice users understand collections?
2. If yes, how are these representations useful? What do they mean to the users?
3. Do the representations need to be improved? If so, how?

We investigated these questions by conducting a qualitative exploratory study. The study employed a series of methods in order to triangulate the results.

This paper describes the study in detail. In Section 2, we present the background information on existing methodologies for evaluating collection understanding tools. Section 3 describes the prototype, VICOLEX. Section 4 relates the methodology. The results of our study are presented in Section 5, followed by the summary and conclusions in Section 6.

5.2 Background Information

Designing an evaluation study for VICOLEX posed several challenges. First, since VICOLEX is a prototype, traditional evaluation methods (such as IR tasks, controlled experiments, usability studies, and others) were not fully applicable. HCI literature suggests that, with prototypes, traditional methods are not able to uncover improvements necessary for usefulness (Mirel, 2007). Therefore, instead of controlled experiments with tasks predefined by evaluators, researchers often use concept testing, think-aloud protocols, interviews, questionnaires, and other qualitative instruments, since qualitative techniques allow gathering more detailed information about tasks (Wassink, Kulyk, van Dijk, van der Veer, & van der Vet, 2008). Second, there is a lack of proper methodologies for capturing hypothesis-making, reasoning, and other cognitive outcomes in order to measure understanding. The difficulty is that such outcomes largely depend on cognitive abilities of the users and their prior experiences with collections. Such challenges have been articulated in many recent papers (Plaisant, 2004; Shneiderman & Plaisant, 2006; Mirel, 2007; Slaney & Russel, 2005).

Despite methodological difficulties, a number of tools for collection understanding have been designed (see, e.g., Chang, et al., 2004; Hilliges, Holzer, Klüber, & Butz; Ahonen-Rainio, 2005; Cunningham & Bennett, 2008; Bainbridge, Cunningham, & J.S., 2004; van Gulik, Vignoli, & van de Wetering, 2004), and evaluated (see Slaney & Russel, 2005; Cunningham & Bennett, 2008; Ahonen-Rainio, 2005). Some of these studies are not exactly about collection understanding or sensemaking. They primarily investigate decision making and information understanding activities which share many common features with collection understanding. For example, decision making and dataset selection described in Ahonen-Rainio (2005) depend on understanding of retrieved results; without collection understanding, the selection would be impossible. Since the boundaries among these tasks and activities are often blurred, as in the example above, we regard such studies as relevant to collection understanding.

From these studies and tools, we can conclude that collection understanding activity has many different interpretations. These differences are primarily associated with the interpretation of "collections". Cunningham & Bennett (2008), Bainbridge, Cunningham, Downie (2004), and Slaney & Russel (2005) view a collection as a set of digital documents, images, or music files represented as thumbnails or symbols organized in a collage or shown on a spatial visualization. Van Gulik, Vignoli, & van de Wetering (2004) and Hilliges, Holzer, Klüber, & Butz (2006) design representations of collections from metadata and tags, thus representing facets and hierarchies in collections. Chang, et al.

(2004) use both metadata and document representations (i.e., images) to represent a collection. Ahonen-Rainio (2005) represents a collection as a set of items with qualities (e.g., updating frequency, scale, geometric structure, price, and number of geometric objects) described in metadata.

Because of different interpretations and, consequently, representations of collections, the studies report different outcomes of understanding. While Cunningham and Bennett (2008) report that their study participants were able to understand mainly document formats, Ahonen-Rainio (2005) reported that her study participants were able to understand quality of datasets (i.e., updating frequency, scale, geometric structure, price, and number of geometric objects) encoded in the representations. Her participants could later use their understanding of quality for making informed decisions about the most relevant items. The subjects in Cunningham & Bennett's (2008) study were able to understand less than the subjects in Ahonen-Rainio's (2005) study, because the collages in Cunningham & Bennett's (2008) study represented only formats, but not other qualities or properties of documents as the representations in Ahonen-Rainio's study did.

In addition, Slaney & Russel (2005) showed experimentally that not only collection representations can either enhance or inhibit collection understanding, but also interactions with representations may affect understanding. Slaney & Russel (ibid.) compared understanding of three different types of collection representations. The first collection was in print form; the second collection was represented on an interactive spatio-temporal visualization, where documents were encoded as clickable symbols; and the third collection was represented in a spatial visualization. The finding in their study was surprising to authors — none of the visualization tools worked as well as the paper collection; the participants were able to understand and comprehend the content of paper collections better than any visualized collections. The major reason behind this finding was a difference in interactions with representations. The paper collection in their experiment was the easiest to interact with. Although the study participants were able to understand the content of the collections from other representations as well, the process of understanding the spatio-temporal and spatial representations was very tedious and time-consuming compared with the print form.

Another important factor that affects collection understanding is users' cognitive abilities and background. Cunningham and Bennett (2008) observed that the participants are best able to come to an accurate understanding when they can draw upon previous experiences. Slaney and Russel (2005) reported that reading speed and other cognitive abilities affect understanding. Mirel (2007) emphasized that understanding relies on identifying patterns in data, but not all users have an ability to recognize patterns and link them with their previous knowledge.

The methodologies used in collection understanding studies may not always measure users' understanding of collections adequately. Some evaluators simply do a usability testing of tools. For example, Chang, et al.'s study (2004) focused on usability of a specific collaging interface. Such studies do not look at the whole task of collection understanding and do not examine objectively what sorts of insights users glean from viewing visualization. Other investigators measure time and error as dependent measures, and record inferences (Cunningham & Bennett, 2008) or measure comprehension (Slaney & Russel, 2005). Although such methodologies are generally considered more objective for detecting insights and measuring understanding, the outcomes of such studies largely depend on users' cognitive abilities (Shneiderman & Plaisant, 2006). A third approach, using qualitative measures (see, e.g., Ahonen-Rainio, 2005; Black, 2010), relies on interviews and think-aloud protocols for testing the utility of representations for understanding the collections. Such methodologies are suitable for concept testing of prototypes and new ideas. Although interviews and think-aloud protocols cannot measure any real outcomes of understanding, they can collect subjective opinions about novel representations.

5.3 Prototype

VICOLEX is a high-fidelity visualization prototype for making sense of library collections (see Chapters 3 and 4 for a detailed description of VICOLEX). The reason we chose a high-fidelity prototype rather than a low-fidelity one (e.g., paper- or video-based) is because the conceptualization of VICOLEX is difficult to present in any other way. As a high-fidelity prototype, VICOLEX looks much like a final application: it gives users a clear impression of the future product, allows them to experience all of its benefits and shortcomings, and see whether or not the prototype meets the needs it aims to fulfill. Although the high-fidelity prototype resembles a final product, we intentionally gave users a simplified version to evaluate. The reason for this is, in finished products, users tend to focus on heuristic evaluation which emphasizes interface functionality and design, whereas in prototypes, they pay attention to the conceptual design. The purpose of the study was to evaluate the conceptual design; and the chief goal of the prototype in the study was to serve as a communication device between the designers and the potential users for determining the suitability of the conceptual design.

The simplified version of VICOLEX allowed users to focus on the effectiveness of graphical representations for facilitating collection understanding. The prototype shows a collection of 349 documents from the Library of Congress Catalogue. In the context of our study, this is a collection of metadata records from one bookshelf (all the books have identical call numbers – DK 508 – and are about the "Local History of Ukraine"). This collection has a hierarchical structure: while the whole collection is about Ukraine, sub-collections within it are about specific locations in Ukraine. The sub-collections are linked to the locations they are about (see Figure 5.1). Each sub-collection can have a number of documents (e.g., there are 92 documents about Kiev; 78 about Lviv, and so on). These numbers are shown on the markers on the map in Figure 5.1. Sub-collections are represented using graphical representations that show various ontological properties of the sub-collections, namely, book sizes, languages, years of publication, subjects, places of publication, and authors. Scatter plots show book sizes and languages; pie charts show languages; histograms show years of publication; KMs show subjects; embedded maps show places of publication; and tag clouds show authors. Overall, VICOLEX has 192 representations that describe sub-collections of 32 locations.

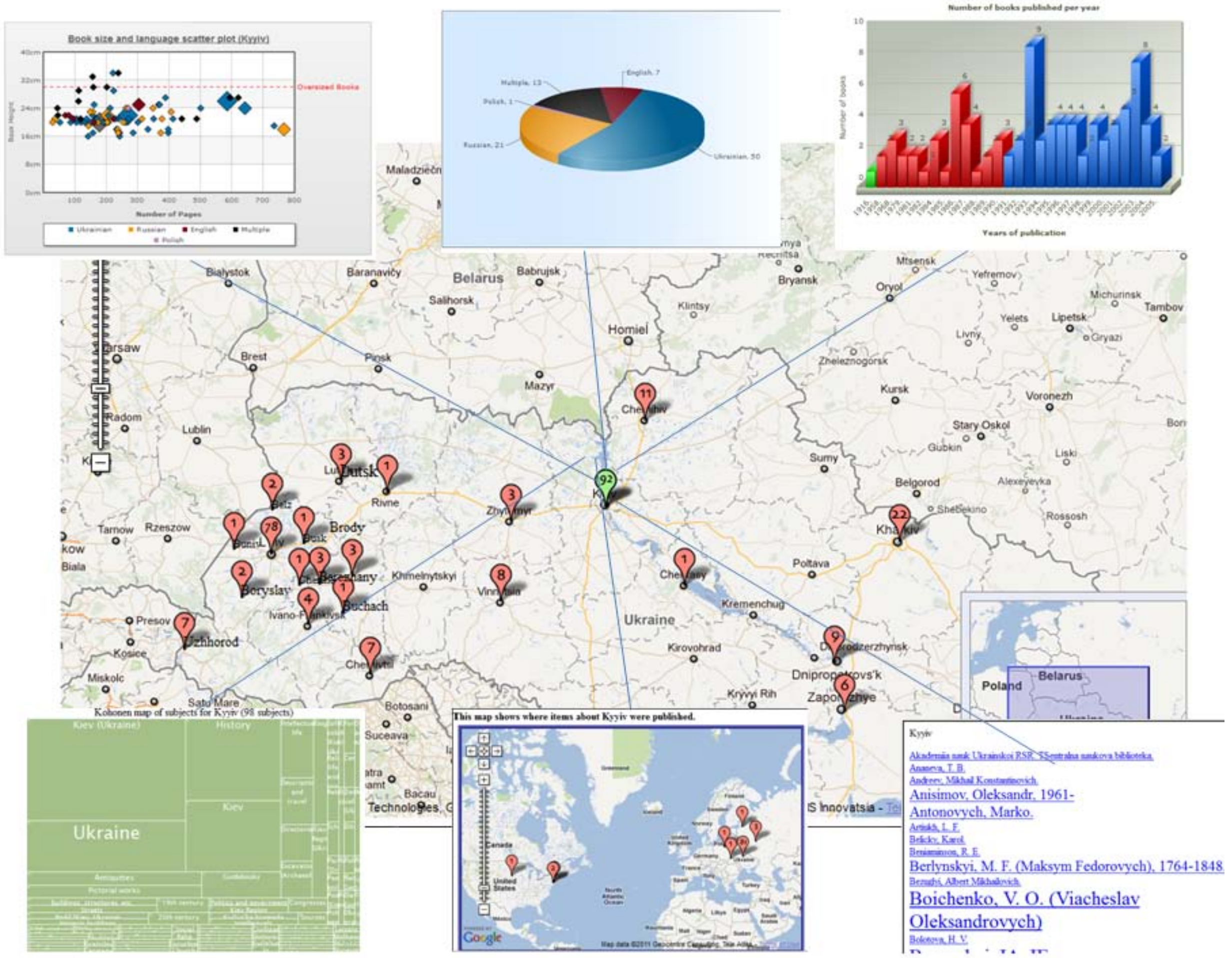

Figure 5. 1 VICOLEX.

VICOLEX has several interaction possibilities. For example, markers can be opened and internal information can be browsed. Various parts of the additional representations inside the markers' information windows are interactive too. They can be clicked on to expose metadata records. In addition, KMs can be enlarged, scrolled, and probed; tag clouds and embedded maps can be scrolled.

Our assumption that VICOLEX can support sensemaking and understanding is based on the utility of its representations and interactions. VICOLEX dynamically generates all the additional representations and links them to locations. Linking interaction along with dynamically-generated representations generates for users meta knowledge about collections, which users can make sense of while "walking"/navigating from one location to another and observing properties of different collections.

5.4 Methodology

In order to evaluate the effectiveness of representations in facilitating understanding of collections, a study was conducted at the Faculty of Information and Media Studies (FIMS), University of Western Ontario (UWO). The study took place in a controlled environment with individual participants. The duration of each session in the study ranged from 86 to 140 minutes per participant. Each session included a think-aloud activity, an interview, and a demographic questionnaire. The study was preceded by a pilot study. The details of both are explained below.

Participants: Thirteen (13) participants were recruited via email from FIMS. Participants included graduate and undergraduate students, faculty, research and administrative staff.

The true population interested in this visualization are users of Slavic collections (e.g., historians studying Eastern Europe) or patrons interested in genealogical research. However, to judge pros and cons of the prototype, besides background in Slavic languages and history, the study participants had to be able to comment on the fitness of use of representations for representing library metadata and classifications, and to have basic familiarity with Google Maps. Finding experts in all these areas was not easy. For this reason, we decided to recruit experts in some of these areas, but not all of them simultaneously. Specifically, we decided not to recruit experts in Slavic languages and history. Unlike other studies that recommend to investigate collection understanding with experts in a subject, we intentionally recruited non-experts since we wished to test the assumption that our visualization can assist novice users (i.e., non-Slavic users) in collection understanding activities. Such a sampling of users may suggest a potential bias in the results, and the feedback provided by non-experts might be considered to be not as good as that of expert users. However, we think using novices was a strength, rather than a weakness, of this study. If a visualization enables novice users to understand foreign language collections without them being able to read documents in foreign languages, such a visualization might facilitate much more than collection understanding alone. Specifically, such a visualization might increase the utility of library catalogues and collections that currently suffer from low usage.

We recruited a diversified sample of 10 females and 3 males. Among them were 2 PhD students, 3 faculty members (two of whom had taught collection development in the past), 1 graduate from the MLIS program, 1 MA-holder in economics, 1 MA student in media studies, 1 undergraduate student from the Media Studies program, and 3 MLIS students. The participants came from various academic disciplines (including economics, sociology, geography, political science, arts, foreign languages, and classical studies). The participants ranged in age from 19 to 60 years of age: 1 participant was a teenager, 2 were in their twenties, 4 in their thirties, 1 in his/her forties, 2 in their fifties, and 1 in his/her sixties. A similarly diverse sample of users from the Penn State community was used in Edsall's (2001) studies of health geovisualization. The reason for recruiting a diversified group of participants was to collect data from participants who had varying degrees of knowledge of metadata, classifications, and library catalogues. Any volunteers (except one) who were known to be taking a course with the researchers involved in the study were excluded so as to eliminate any potential concerns of coercion. The exception was a participant whom we realized was an exception only after the participant completed the study. To avoid any problems with coercion, his dataset was analyzed after the semester was over.

All participants were experienced computer users, having used computers for 10 to 35 years. Four identified themselves as expert users; 7, as intermediate; and 1, as intermediate-expert. All of them use Google Maps: 4 sometimes, 8 often, and 1 frequently. The level of proficiency with statistical graphs varied from expert (2), to intermediate (7), to novice (4); and experience with information visualizations ranged from novice (8) to intermediate (5). With regard to experience with classifications, participants characterized themselves as follows: 1 – expert, 7 –intermediate, and 5 novice, and for experience with the Local History of Ukraine collections they characterized themselves as novice (12), and 1 between novice and intermediate.

Pilot study: A pilot study preceded the actual study. Two subjects were involved and their input was used to correct problems with and determine if anything was missing from the study design and to enhance the usefulness of the semi-structured interview questions. The pilot sessions allowed testing the timeline of the study and identifying problems with the screen capture software and the interview design. The initial pilot study was not very successful because the study participant was asked about collection understanding without having the task properly explained to him/her. For the second pilot study we redesigned the think-aloud protocol and the interview to make it easier for users to understand the task. Specifically, we introduced visual tasks as subtasks of collection understanding. Although, visual tasks are not known as ecologically valid questions for evaluating visualizations, we used them for indirect evaluation, that is, for training participants to complete the collection understanding task. This approach was quite successful, hence, we decided to use the data from the second pilot for analysis. For this reason, the total number of participants reported in the remaining part of this paper is 13.

Study design: The actual study comprised of the following phases: demonstration, think-aloud protocol, interview, and questionnaire. The scheduled timeline for each session was as follows:

- Initial greeting, explanation of the study, and signing of consent forms (10 minutes)
- Think-aloud protocol (40 minutes)
- Interview (45 minutes)
- Questionnaire (5 minutes)

In reality, sessions lasted from 86 (1 hour and 26 minutes) to 140 minutes (2 hours and 20 minutes). All participants were rewarded with coffee gift cards for their participation in the study.

Demonstration: At the beginning of the study the investigator demonstrated the visualization, and explained what it was about, how to look at the representations, and what to pay attention to in the representations. The demonstration was important, because it allowed users to know where to start and how to use the prototype. Other researchers who have evaluated geographic information systems or map-based interfaces have also emphasized the importance of tutorials before evaluation studies (Ahonen-Rainio, 2005; Edsall, 2001; Andrienko et al., 2002). Although, our study had an advantage because the prototype visualization was based on Google Maps (which has become a staple for navigation, geospatial information finding, and mashup building on the web (according to ProgrammableWeb.com), other representations linked to Google Maps in VICOLEX required more explanations because they were new to the participants. The participants were allowed to ask questions during the demonstration period.

Think-aloud protocol: The think-aloud technique is a way of eliciting feedback from users and understanding what is going on in their heads (Erickson 1995). The technique requires subjects to say out loud everything that they are thinking about and trying to do, thus externalizing their thought processes. Norman (1993) and Sasse (1991) consider that, for determining the “effectiveness” of a system (or, in our case, representations) in problem solving, thinking aloud techniques are superior to any quantitative measures, because during think-aloud sessions people can explain why they like or dislike certain features. Jonassen, Tessmer, & Hannum (1999) note that novice users can be regarded as ideal subjects for the think-aloud protocol, because it is easier with them to identify misconceptions and errors associated with tasks or representations.

During the think-aloud protocol, the participants were given two sub-tasks. The first sub-task had two practical goals. First, we wanted to teach the participants how to use the visualization and what to look at while exploring the representations. Second, we wanted to explore the effectiveness of the graphical representations for visual tasks. For this reason, the participants were asked to perform visual tasks on each additional representation about the Kiev collection, the largest sub-collection in our testbed collection. Some sample questions users had to answer included: What is the average book height in this subcollection? What book has the largest number of pages? How many books are oversized? What genres do these items belong to? Participants were asked to think-aloud while answering the questions, and report any difficulties with the representations in VICOLEX. We did not record how long it took participants to answers the questions because we did not want participants to feel any pressure while they were still learning the application features.

For the second sub-task, the participants were asked to browse collections of other cities from both Western and Eastern Ukraine (anywhere from 1-2 large, and 2-3 small cities). While doing this, they were asked to externalize their thought processes and report any similarities, differences, and trends in data they observed. This sub-task was a very important part of the study. Here, the participants were able to demonstrate their understanding of collections objectively, since, understanding, from the point of view of cognition, is the ability to make connections (see Background section). As participants consecutively browsed collections, they were able to identify connections, trends, and dissimilarities between collections they were currently viewing and earlier-viewed collections.

Interview: The think-aloud protocol was followed by a semi-structured interview involving a discussion of the participant's understanding of the collection as a whole, their thoughts as to the usefulness of the representations, and the applicability of the representations to other collections. The interview questions included general questions about the effectiveness of individual representations in collection understanding and more specific questions about particular representations, especially those that are criticized in research studies - KMs and scatter plots (see, e.g., Kobsa, 2001).

Questionnaire: At the end of each session, participants completed a brief questionnaire that asked for demographic information, their prior experience with statistical graphs, metadata and classifications, Local History collections of Ukraine, and information visualization representations.

Drawbacks and limitations of the study: The primary drawback was the impact of the researcher's presence in the room as the participants went through the process of developing understanding. However, in studies examining user behaviour, this drawback is outweighed by the benefits of being able to observe the user's behaviour first-hand as he/she works through the interface or thinks about how to perform a task (Krug 2006, 131-159).

Another limitation was the artificial setting in which the study took place. Participants worked on developing understanding in a usability lab instead of their own workspace. They had to finish the activity in a set amount of time. Also, they had to develop understanding only from the representations selected by the researcher and could not use additional representations of their choice. In other words, the study design did not recreate a completely natural setting for the collection understanding activity. These limitations were necessary, however, to ensure that only the work with representations was observed (as opposed to in-depth reading, triaging, and other activities) and to obtain the various data sets (audio, video, and direct observation). Moreover, a full-scale ethnographic study of collection understanding was outside the scope of this specific study.

Data collection: During the think-aloud sessions, participant impressions, along with their activities, were recorded with CamStudio, the screen capture software, and Audacity, the audio recording software. CamStudio provided an audio/video log of the collection understanding activity including the participant's mouse movements, keyboard input, and any comments the participants made during the process. In addition, participants' reactions to the representations, first impressions about design ideas, and wait periods, which were not captured with the screen capture software, were recorded in notes. Interview sessions were recorded with Audacity software. Participants were informed of the recording methods being used and this information was included on the consent forms.

Using the technology and taking notes allowed collecting data from 4 sources: 1) transcripts of think-aloud sessions from CamStudio; 2) transcripts of think-aloud sessions from Audacity; 3) transcripts of semi-structured interviews; and 4) transcripts of direct observations recorded by the moderator during the sessions. The data included both objective and subjective evaluation, thus allowing the triangulation of results.

Coding: The interviews and think-aloud protocols were transcribed using ExpressScribe software and entered into the MS Access database, which served both as a collection tool and a coding tool. Each participant's data was distributed across several tables in the MS Access database. Each participant was given a unique ID number with which all tables were linked, accessed, and queried. To avoid coder incompatibility, the data was coded by one researcher. In the first think-aloud session, during which the participants were asked to complete visual tasks, the correctness/incorrectness of their responses was coded with "correct/incorrect" codes. Later the numbers of correct and incorrect responses for each participant were calculated.

All other comments from think-aloud protocols, discussions from interviews, and observational notes were coded with a grounded theory approach outlined by Corbin and Strauss (1990). First, interview questions and think-aloud sessions were grouped by representations and then reviewed for the purpose of assigning other codes. Codes were assigned to the key points in different parts of transcripts. Later, similar codes were grouped together into facets and added to the coding scheme. This allowed drawing conclusions about reasoning patterns, merits, shortcomings, improvements, and usability of different representations. Our goal, with this approach, was to discover various pros and cons of representations and find objective evidence that representations could help participants reason about collections. Once some evidence or property was identified in an interview or think-aloud protocol with one participant, other transcripts were checked for similar evidence, and then similarities and dissimilarities were compared. Coding was refined in several iterative cycles until all concepts and themes were interconnected. Finally, when all codes were grouped by themes, screen capture videos were used to find supporting evidence. Examples were transcribed and merged with other data. Videos were also used as backups when audio files were inaudible.

5.5 Results

This section presents the results of the study. General findings about the utility of all representations are presented first. These are followed by findings about individual representations: pie charts, histograms of years of publication, KMs, scatter plots of book sizes and languages, representations of places of publication, and author tag clouds. The latter are presented in the order of their effectiveness to facilitate understanding (from the most effective to the least effective).

5.5.1 General Findings

All participants answered positively that additional representations can enhance understanding of visualized collections. According to one participant, additional representations are useful primarily because they predict questions that users might ask about collections. As a result, it saves users time and effort: they no longer have to process information; they no longer have to ask questions, think of keywords or subject headings, because representations announce the structure of the information. One participant admitted that before using visualizations to view a collection she had to draw pictures in her head. However, with the visualization she was able to get the top data without having to process the data.

Not only do representations show the structure of the data, they also add interpretation to the data which are typically neutral in library catalogues. For example, representations make geographic references more meaningful and explain historical time periods, languages, and subjects pertinent to each location. One participant described her experience with the visualization as follows: "You get that kind of sense: Oh my gosh, Poland is right there... When I think about Ukraine, I have no idea where it is in my head and my mind... somewhere in Europe. But having geography visible I think it makes just like that... It felt to me as I was travelling. Oh, I am visiting a place. It was not like about data, it was about a place. Or maybe it is just me. And then these representations were like book stories about each site. It was not just like a list of books. It was like story telling. That is my interpretation. ... That's my experience of it. I did not get a feeling when I was exploring data in the Excel chart... This visualization had kind of cake to it, it was more fun. " She also stated that the story telling capability of the tool challenges the boundary of having libraries as neutral entities and adds a little bit of interpretation to their work. In her opinion it was helpful, interesting, and fun. Other participants also stated that the representations gave them a better understanding of the type of city they were looking at (e.g., whether it is a big tourist location or a small location), about political events and other changes associated with locations, and about ties to other countries. They also said that the graphs and charts not only gave numbers of how many books there were, but provided much more information about the collections of which participants were unaware. For example, they had no sense of publishing trends and policies, of the literature, and of the language of that location.

Representations allowed participants to see trends more easily than with traditional tables or metadata records. One participant recounted his experience as follows: "If I were just looking at a table of records, it is very possible, especially if the titles are difficult to understand, I would just walk away ... I might be more interested in ... there are different sides to look at. And you can ... understand it easier with charts or graphs...." Another subject commented: "It enhances metadata, which otherwise is not used." Here is how a third participant relayed how a representation was able to catch her attention: "That one publication on the first task ..... couple years after, during Soviet Union it had a surge. Ah, it became interesting. It became just immediately apparent ... so it really enriched the way the stuff was presented. And visualization is easier to grasp rather than data." These comments can probably be explained by the representational capability of visualizations to make data stand out, make it salient, crystallize knowledge about data, and appeal to users (Card, Mackinlay, & Shneiderman, 1999).

Participants also found that the visualization tool worked particularly well on the prototype collection used for this study. One participant's comments describe why: "The Ukraine is very interesting endeavour because depending on what city you are the languages change from Russian, to

German, Polish,... so that was really interesting. It really enhanced the data. I would never have thought of Ukraine that way. It has extremely rich history." Such a visualization, however, might not work so well for some other collections. It depends on whether or not the data is interesting. If the data is flat then it is not interesting. One participant noted that people like the wow factor; if there is no wow factor, then it should not be visualized. She gave an example of England: "Well it might be multilingual now, but before it was probably 92% English..." For this reason, she did not see the need to visualize languages for such a collection.

Generally, for the completion of the given sub-tasks, each type of representation assumed a distinct function for the users' exploration. Subjects used Google Maps to orient themselves in the collection. They used additional representations to explore and interact with particular sub-collections, learning about the properties of those sub-collections. The distinct functions of representations complemented each other and exposed users to different aspects of the sub-collections.

5.5.A Pie Charts

All participants found pie charts useful for facilitating collection understanding. They were identified as the most important and easy to use representations. One participant stated that she thought it was probably one of the most useful representations because it was easy to look at and to quickly identify the most represented language. Another participant stated that pie charts were especially interesting about Ukraine, because each city had a variety of different languages. For monolingual locations, however, pie charts might not be very interesting because they would look flat.

Participants identified several reasons why they thought pie charts were useful.

1) Since language is an important access point, it is important for a user who is looking for documents in a particular language to see the language distribution of a region. Pie charts can help users find a particular language.

2) Pie charts can show shifts in language dominance in a region. For example, a public library that exists in what is initially a Polish neighbourhood might have primarily Polish publications at first. But, as the population of the community changes, the publications might gradually change to English. Pie charts can show the change in the languages of publication in a region, as the population of that region changes.

Pie charts allow users to infer additional information about a location. In our study, participants were able to generate hypotheses about places and identify spatial trends based on the pie chart visualizations. For example, one of the participants asserted that when someone could see that many languages are spoken in a location, then that location would probably be better for travel. Other participants said that studying the language distribution of a city using the pie charts helped them make educated guesses about the geographic location of the city within the country (e.g., Polish is predominantly spoken in the far West of Ukraine, the East is more heavily Russian, and Ukrainian is dominant in the West). One of the study participants noted that the capability of pie charts to facilitate hypothesis generation and trend identification could have general interest in Canada because of the multicultural communities in large metropolitan areas, and the use of multilingual library collections.

5.5.B Histograms of Years of Publication

After pie charts, histograms of years of publication were identified by study participants as their favorite visualization. Twelve participants were confident that histograms could facilitate understanding of the collection. One participant initially disagreed, but later changed his opinion to a more positive outlook. Here is how one of the participants explained her preference: “I think it provides quite fascinating information. I think without it it is a little bit flat. You kind of getting general sense of what has been published throughout the history.” Histograms helped participants identify differences between publishing activities during the Soviet Ukraine and independent Ukraine. For instance, they were able to see that not many publications were published during the Soviet years, but more was published after

Ukraine became independent. They could also understand how far back the collection goes, how books are associated with historical periods and in what political climates books were published. They could also identify years where there were gaps in library acquisitions. One participant said that histograms helped her realize what was going on in the collection and what sorts of subjects the books were going to cover.

The participants found the use of colour to identify different categories in the histograms very useful. This allowed participants to quickly compare time periods. Some participants indicated that categorization was especially useful "in this kind of case when a place changed based on government." Although the categories presented to participants did not seem to create any controversy, one participant talked with some caution regarding the categories: "I do not know whether information like this will ever be controversial ..... controversy on dates or names, or things like that. I have no idea. I do not know about that with respect to different countries, or if that would create some sort of conflict. But I find it interesting." An example of possible controversy within a Canadian context was given by another participant: "In Canada we also have a landmark –the day of Canadian Confederation. If you talk about First Nations people they might not agree with that landmark. They might have a different landmark."

Colours in histograms have been credited by the study participants with providing enhanced understanding, not only of collections but also of the history of regions and the historical relationship between neighbouring regions. One participant described how histograms helped her make sense of a part of the world about which she had little prior knowledge: "I've lived in North America for 30 years now. Before that I lived in the Philippines. Last year because of the interest that I have in holocaust I went to Poland. That was the first time I realized that I did not know much about Europe. You know, Poland was under this, under this that. I had very little knowledge about European history except for Spanish history, because I studied that. But it is interesting to see connected history map with Europe. I grew up thinking Russia — USSR. So I was not much familiar with Ukraine... So coming from ... from other side of the world this is beginning to make sense to me. ... I also see the struggle... In the Philippines people are often upset with the Spanish that we were ... for 300 years. The same story here, instead of one country, you have different countries: Ukraine, Poland, Russia."

Histograms helped participants gain greater insight into political and economic events, economic or technological changes, and the economic situation of publishing. This information was inferred from time periods and numbers of items published during each period as shown by the histogram visualizations. A typical analysis of a histogram by one of the participants is as follows: "... I wondered why there were 4 books published in the Soviet Union as opposed to one. And then it was the matching with anniversary or so. I looked at them, looked where they were published, and things like that. Again the difference in economic trend too, where we can see in 8 years all of a sudden [a spike]... You sort of see other stuff going on there." Another participant stated: "... years told me a lot about the economic situation of publishing, which in my head automatically went to... that is good to know, particularly, because more writing does not necessarily mean better writing. One tends to be more market savvy... So that you can see that happening [here] ...: even though in the Soviet period writing was what you can write, during the independent Ukraine you can write economically. You are still subject to one way or another."

The majority of the participants expressed that histograms could also show the history of disciplines. One participant justified this as follows: "It gives you the sense of scholars that are working on ... This was great, this was great. It may just be in terms of years of publication; that is something that I have a lot of experience with. Years of publications are used to describe the structure of the literature. And because I am also an information behaviour scholar when I look at the information practices, scholars and practices — this is the history of the discipline as well. So people work on these particular topics very little at the beginning — it does not surprise me."

During the think-aloud session, participants often used histograms to draw conclusions and to reason. Here are a few examples of reasoning statements, generalizations, and inferences that participants made based on information they gathered from the histogram visualizations:

- "So, that tells me something about literature: one explanation, the economy gets better; the other explanation, there is freedom of speech is there, people are publishing more ... publications policies change..."
- "So again, not a lot of things published. A big year 1984. (4 titles) and more gaps, after that more consistency. All that points to some anniversary or something." [That city celebrated a 200-anniversary in 1984].
- "This collection has been more stable in the development over the years."
- "Books from the left part of the country were mostly published in blue period, whereas in this part of the country — many books were published in the red period." [Blue represents Independent Ukraine; red represents Soviet Ukraine].

Participants identified some shortcomings of the histogram, and a few improvements were suggested. Proposed improvements included adding better representations for the periods of gaps in publishing, adding colour codes to the legends, and improving/increasing interactions of the visualizations with subject headings on the Kohonen Map. Another suggestion was to change the histograms from a 3-dimensional to a 2-dimensional format. Participants noted that when sitting at an angle to the computer screen, the histogram bars seemed skewed in the 3-D format.

In addition, after seeing histograms used to categorize a collection based on significant historical periods, users suggested using histograms to categorize collections based on other events. For example, a participant suggested that users interested in women's studies would prefer a timescale based on legislation related to women's suffrage. Alternately, historians studying the holocaust might prefer to use a timeline based on Soviet and post-Soviet rule because before the fall of the Soviet Union, the history of holocaust museums was represented in one way in the East, and another in the West (in the West historians focused on Hitler, while in the East the focus was on fascism). However, this does not necessitate that local timelines have very detailed categorizations. As noted by a few participants who were not involved in any kind of research, the nuanced, highly-detailed categorization of years of publication might not always be useful. For users with limited knowledge of political leaders or regimes, more specific categorizations could become overwhelming and too difficult to understand. Instead, participants preferred to have the option to choose a suitable timeline for their needs.

5.5.C Kohonen Maps

KMs received mixed reactions from the study participants. Three subjects were confident that KMs enhance understanding; one subject thought that KMs do not provide adequate support for understanding (stating that, "I would not use it, I don't think this one works."), and others thought that KMs could be useful only if certain improvements are made.

Study participants found KMs useful for enhancing collection understanding because they provide overviews of subjects and show concentration of subjects for different locations. KMs generate alternative views that can be superior to the ones users are accustomed to seeing in library catalogues. Here is how one of the participants explained the utility of KMs: "It is like an alternative to the catalogue where there is only a list of things that people do not quite understand. Here it collects them in a different way so that you can see which city has more subjects."

Another reason why participants found KMs useful was because, unlike text-based catalogues, KMs are graphical. A couple participants found the graphical form of KMs easier to understand and more enjoyable than text because displaying subjects on such a map makes the language immediately apparent. When users explore such maps they do not have to overload themselves with query terms; instead these maps show users what subjects are available. "Users just have to look around and say that they are interested in this and this over here," stated a study participant. This feature makes KMs similar to road maps and story representations.

A few participants also noted that KMs enabled them to identify trends in different locations. For example, during the think-aloud session, many participants noticed that all KMs contained geographic subject headings about locations to which they were linked (e.g., subjects "Lviv", "Lviv (Ukraine)," "Ukraine" can be found in the collection about Lviv), and some other high-frequency subjects such as "History," "Biography," "Antiquities," "Pictorial works," and others. Seeing this trend, one participant stated: "A lot of it is the same. Most of them had "History" (really big one). So it did not really provide anything." During the study, however, as participants gained more experience using the KMs, they noticed new subjects as well. Below are a few participant statements recorded during the think-aloud session:

- "I don't remember seeing "Poles"..."
- "Oh, I did not notice before – "Austria"... There are some [subjects] that repeat, there are some that don't."
- "Meanwhile, "Excavations," "Antiquities," not quite as many ... things like "Guidebooks"........ "North America" comes in..."

KMs were found to have a number of shortcomings. The usefulness of KMs seems to decrease with the number of subjects they represent. The more subjects KMs have, the more cluttered they look. One of the participants described her experience with a cluttered KM as follows:

"If you have a lot of items, you have a few of them that take up the whole center, and then you have all these small subjects. These small subjects can be as important as the most numerous one because that one chapter could be very important. But the font is so tiny and it is really hard to read it."

Other participants commented that large KMs are very skewed on the sides, and have very large sets of data on the outside. This makes users feel lost and confused about smaller categories on large

KMs. In such KMs, the compression of KM labels, especially long ones, makes them inaccessible. Therefore, a few participants were concerned that for large collections such as ones in New York City, KMs would be huge and unusable.

Another reason users found large KMs to be difficult is that they are hard to comprehend and process. This is evident from the following complaint:

“I can take fewer things... I can't handle this many. This [pointing to a large KM] to me looks like a blueprint of a hospital which is a map, right, with a variety of rooms. But this [pointing to a small map] actually looks like a mid-sized floor plan. This one looks like ... so I can go easily get to my destination, here it would not help me to understand here, because there are so many corners and things.”

Another participant noted that limited KM size is particularly critical for netbook and smartphone users who have small screen displays. Users are used to interacting with large displays and large representations. However, researchers need to consider how interactions might change when large displays are fit into small screens, making it difficult for users to read and perform visual analyses.

During the interviews, participants identified those KM layouts that they considered to be ideal for reading. Such KMs contained from 7 to 15 subjects. In such KMs, every subject seems to get a fair share and the labels are much easier to read. The number of nodes in the KM depends on the orientation of shapes. The shapes on the sides should not be excessively skewed, and labels have to be legible. In general, participants commented that visual representations should be easy to read and understand.

Participants found that shapes in KMs can sometimes be misleading with regard to shape area and font size. For example, a few participants had problems comparing horizontally and vertically oriented shapes. One of the participants explained this difficulty as follows: “Somebody who looks at it all the time, might say about that large square: there are more subjects under that subject, and then you have to find a small area... but you are not sure whether that is any different from that because you have to calculate vertical vs. horizontal....” But, even if participants managed to identify shapes with identical areas, the shapes were still misleading because they did not always have the same number of linked items. This is evident from the following observation: “”Guidebooks,” “Biographies” here they look like they are going to have fewer topics on them. But then you look at the “Civilization.” It seems that it should have more items, but it does not. It is like comparing apples and oranges.”

Another shortcoming of KMs in VICOLEX is that relationships among subjects are not visualized. For example, one of the participants noted: “You can't look at that and you can't say: ok, it's “20th century-Guidebooks-Kiev.”” Participants with a solid LIS background felt this could be misrepresentative of a collection, particularly if a book falls under multiple subjects. “Let's say you have 50 books on history, but they [are] also on multiple other things but we don't know what they are. I do not know whether you can get a full understanding of the collection actually is about.” For other users, who were less library-savvy, the lack of visualized relationships among subjects was not a serious drawback. Here are some of their comments:

- “For users they are the same as subjects: in fact they are easier to understand”
- “Nobody knows [library subject headings] anyways.”
- “I do not think that we need these strings.”

One participant, however, thought that KMs do preserve subject heading relationships to a certain degree. She gave the following explanation: “Just because you click on the city and then you see subjects describing that location. Even though we do not have a hierarchy, I still think that it is better than just listing subject headings from the catalogue.”

Study observations indicate that the probing and scrolling interactions provided with KMs were not very useful. These interactions were provided to augment visual tasks. Probing was intended to assist participants with deciphering long or hard-to-see subjects. It was implemented such that the selected nodes were overlaid with the tooltip. All tooltips were temporary and went away when users moved the pointer to another subject. Scrolling was intended to help participants overview large KMs. In the study, it appeared that both interactions slowed down participants in their ability to make comparisons and identify trends. Typical participant comments included: “If you get to a city like Kiev which has many subjects, that's a little hard, and you do have to scroll a lot.” Participants complained that they could not see subjects all at once, nor could they compare or remember them. As a result, they could not visually compare all their choices, had to rely on short-term memory, and were reduced to playing “mine sweeper” with the mouse to discover subjects on the map. This sort of use of the scrolling tool was discovered after analyzing video screen captures of participants’ interactions with the tool. In most cases, participants would focus on the KM representation during exploration, and therefore might have preferred to see all subjects at a glance.[1]

Regardless of its shortcomings, study participants were enthusiastic about improving the utility of KMs in sensemaking. One user suggested improving the font size on KM labels. Currently, labels do not always correspond to the density of subjects and can confuse users. Just as the areas of rectangles in KMs declare the density of subjects, so should the labels’ font size. In addition, several users suggested alternative ways of making the density of subjects more salient. These suggestions include: using a colour gradient, clustering subjects, adding an alphabetical list of subjects beside the KM, using black rather than white font color, adding interactions such as zooming, filtering, and bifocal lens, and removing some subjects. A selection of these improvements is explained in greater detail below.

Participants suggested adding an alphabetical list of subjects coordinated with a KM. One participant justified this as follows: “Subjects are so hard to look through, but listing them alphabetically would improve the representation.” This is not surprising; cartographers often complement geographic maps with text (Pequet, 2000). The use of graphics with text and vice versa helps overcome inherent shortcomings of both.

[1] In HCI, mine sweeping is not considered a good practice (Nielsen, 2009); labels should be permanently visible.

Some subject headings were recommended for removal from the KMs. One such heading was geographic headings that describe locations to which KMs are linked. For example, in the Kiev collection, geographic subject headings include “Kiev”, “Ukraine”, and “Kiev (Ukraine).” The reason why these can be removed is because they take up to two-thirds of the whole map but are not very useful to users. Users have already made a decision about relevancy of those subjects by having previously selected a marker on Google Maps. Participants thought that removing geographic subject headings would greatly reduce redundancy. One participant explained why these subjects can be removed by using an analogy of doing a subject search in other library systems:

> “Here is the analogy. LISA and Library Lit databases — the last word you should type into them is “library” or “information”. Everything is about library or information. The number of hits is just incredible. Don't try looking for *library*, everything is about library... What we've done here is like searching for library in Library Literature. So it is not necessarily useful.”

All participants expressed the need for filtering, especially filtering by years of publication and filtering by types of subjects. They thought that filtering would greatly simplify KMs. Filters can allow users to focus on a few rectangles, and therefore expedite a visual search. One participant suggested adding a layered structure to KMs: “I think that could be really useful. You have the major subjects represented on top. And then you can click further to see what other subjects. So you have guidebooks represented on the main level, you click on guidebooks, and then it has street names... Could you just do the following: you say I want to find books on history, and then history just pops up and grows into color? You click on history, and it turns yellow, and all related subjects turn yellow. It could show how they all are interrelated.”

Currently, KMs are not a very popular data visualization tool. Users have more familiarity with tag clouds and relational graphs, and, for this reason, understand them better. Nevertheless, a few participants mentioned that in order to fully understand KMs, users require training. One participant asserted that KMs could be very helpful, once users got used to them, and once they understood this visualization.

5.5.D Scatter Plots

An overwhelming majority of the study participants acknowledged the usefulness of book size and language scatter plots for enhancing understanding of the collection. Five participants responded absolutely positively, five "to a certain degree", one said that he was slightly confused, and one participant described her experience as follows: "I do not know whether it gives you a good understanding of the collection, but it is interesting to know." In the opinion of the latter participant, this representation was more informative about outliers than average-sized books.

In general, scatter plots allowed participants to understand book sizes in sub-collections. Based on the results of the first mini-task during the think-aloud protocol, we conclude that users were quite successful at identifying the smallest and the largest books, the average book size, and the number of book copies in the collection, as they did not have many mistakes and knew where to look for the required information. Although all the height and number of pages properties were available in metadata records, participants preferred scatter plots to metadata records to extract this information. One participant explains why: "... seeing it this way I think is better than just having the dimensions. Because if you just saw that the average book size is this, then you could take a quick look and realize that the book you are interested in is bigger than that. It can help you visualize the size of it."

Scatter plots made it easier for participants to identify trends associated with languages and book size in subcollections. Below are a few examples of comments that participants made during the think-aloud protocol, when they were looking at book size representations:

- "I think they had more oversized books. I think in Kiev they are larger and bigger. Maybe because it is closer to the former Soviet Union east side? So maybe that influence is coming in?"
- "22 cm average. Oh, we have one in Hungarian."
- "More books that have multiple languages."
- "I did not see significant differences in the size of items. If they had oversized items, [those were] pictorial works."
- "Almost no oversized books."
- "Not too many duplicates or multiple languages. And again here are a little bit more books that have more than 600 pages."
- "Average book size is still sitting at around 20 cm."

Not only were participants able to identify numeric values from the scatter plots, but also made their own interpretations, conclusions, and hypotheses about the data. For example, one participant stated: "As we saw, there seemed to be a rule that every time when there was an oversized book, it was a pictorial work. Or, pictorial works were also seen on KMs as well. It kind of helped me see ... If I were to find a guidebook with some visuals, ok, that is the way to go." Another participant came to a similar conclusion: "Usually there is no reason for something to be oversized unless something shows some sort of mapping or larger pictures or something like that." A third participant suggested that books with large numbers of pages are more significant. A fourth participant asserted that if one is looking for images, one should look in larger books, because in such books the pictures are going to be bigger. A fifth participant said scatter plots gave her "a sense of economics based on the city."

It was interesting to observe that participants came to such realizations only after completing visual tasks and browsing books for some time. Their interpretations were, in fact, not about properties encoded on the scatter plot (book size and language), but rather about the relationships between book size, content, and economics based on data linked to symbols on the scatter plot. A few participants gave examples where information about book size may play an important role in judging content. Often larger book size indicates books with maps, architectural books, Bibles, pictorial works, and books with fewer images. One participant recounted the following example of the importance of book size from a recent experience she had had: “This reminds me of a book that I had to write a review on... One thing that I noticed with that book and the reason I thought of it was because even the book was fairly large in size and very heavy. It's heavy because it has nice thick pages... But even though the book is so big, it is hard to see some of the visualizations, because it is still not big enough to see the maps that she has in there.”

Book size can also be important for people who have time constraints, when they simply do not want to spend much effort reading a large book, or when they are looking for light-weight books to take with them when traveling. This is evidenced by the following comments from study participants:

- “Again it depends on what ... you are bringing for the search... But if you were doing this with the high school student, when you get that kid that has to do a book report, this could be of great interest to be able to understand how many pages... On the other hand if you thought of <...>’s course on the holocaust that I audited last year, we read that there is a large 3 volume set of history of holocaust ... but we read the abridged student edition. But I thought to myself that if I ever want to do serious research I will have to go look at the full edition...It leads to intent, so I think it is useful.”
- “Then there are small books if you want to pick something for light reading or maybe something that you would like to read while on a train....”

Participants were split in their views on how size information can be important. Some participants stated that number of pages is more useful than height of a book, because the former data provides a quick understanding of whether the work is significant. Others held the view that height is more important. By one participant's account: "Size really helps to find books about architecture. Books about architecture are typically oversized."

Similar to their experience with KMs, participants who were using scatter plots for the first time felt somewhat lost. However, after getting used to them, they actually liked them. One participant even admitted that he would choose a scatter plot over a geographic map because it is simpler for learning.

Scatter plots had some shortcomings. They provided poor support for precise counting tasks. The hardest task was to count all books in Russian in the Kiev collection. Because symbols representing books were distributed spatially on the scatter plot, and some of them overlapped, it was difficult for participants to get a precise count. Some participants simply switched to pie charts when they realized their counts were not accurate. This is not surprising because scatter plots are area representations that present spatially related information. They facilitate viewing the information contained therein at a glance, without addressing the elements separately or analytically. Scatter plots are weak at facilitating the extraction of specific data values, but more effective for point reading (Vessey, 1991).

Many participants reported that the relationship between book size and content is a highly specialized type of knowledge that not everyone uses. This could be because not every collection has unique book sizes and nor does there exist in every collection a relationship between book size and other properties. Moreover, as one participant noted, "at an academic level it would not make much difference what size the book was, except that it means that I can generalize about what language... But just the size is not overly very very helpful." By this he meant that academic books can be of any size, and all sizes could be equally important.

Participants also characterized the scatter plots as overwhelming and confusing when they contained overlapping and cluttered symbols (especially when some of the smaller blocks were over the bigger ones). This made scatter plots hard to read and hard to click on. However, having dense data on scatter plots can also be advantageous since on dense scatter plots "it becomes really clear what the average is... and then at large [collections] it can be really interesting because there are so many of them. If you have only 4 or 5, the only reason why you would notice something odd about them if you compare them with other cities rather than looking at the items in isolation." Some participants used this latter technique. After having looked at the scatter plot for the Kiev collection, whenever they went to other cities, they compared those scatter plots to that of Kiev. So, scatterplots helped with understanding general trends in collections.

It seemed the confusion with scatter plots was often associated with symbol encodings. A participant was surprised to see language encodings on the book size scatter plot. He said: "I do not know whether I really care whether English is 16 cm, or more." He suggested encoding other properties instead of languages. He was particularly keen to see subjects on this scatter plot. Other improvements participants suggested include adding filtering by languages, zooming, encoding to indicate soft or hardcover books, augmenting scatter plots with a coordinated list of titles, and enhancing scatter plots with bars on the sides that show quantities for each book height, number of pages, and measures of central tendency. Alternately, scatter plots can be enhanced by linking them to the coordinated pie charts.

5.5.E Representations of Places of Publication

Embedded maps showing places of publication were found to be useful in enhancing understanding. Eleven participants were confident in their utility, one reported that embedded maps helped a little bit, and one found that they were the least important.

These maps were found useful for multiple reasons:

- Some participants thought that maps reflected changes in country borders;
- Other participants found maps useful for comparing how much was published within or outside a country or continent;
- Others thought that maps would be helpful to see which publishers are influencing

collections and to discover variations in content based on geographic location (e.g., North American publications would differ from European ones, or books published by Harvard scholars would be different from books published by scholars in Ukraine);

- One participant noted that showing places of publication was particularly useful for visualized collections, because such collections about local history are often used for genealogical research. She gave an example of Spanish users who often differentiate places of publication. “If you are from Catalan or Barcelona, you would be much more interested to read stuff from those places than from any other region in Spain where it is probably pejorative because they are imperialists.”

Other collections that participants named as those that need embedded maps are historiography, political science, and history collections.

In terms of objective evaluation of maps in enhancing understanding, three important aspects should be noted. First of all, embedded maps helped a few participants establish connections with other representations within the same locations. When users saw representations of languages, they could not fully interpret them until they saw the map of places of publication. This is evidenced by the following comments made by participants when they studied maps of places of publication: “Now I understand why there were so many Polish books” [because many books were published in Poland], or “Now I understand why there were books in Greek - they were published in Athens.” Second, maps allowed study participants to make conclusions about general publishing trends of collections from different locations. Participants commented on the distribution of places of publication, i.e., whether publications were from local or other national publishers. Third, maps prompted participants to generate questions. This is evident from the following comment: “[I]t might raise questions why was emigration from the Soviet Union to other parts of the world. I can really see the immigration trend... It helps me create that one question. ”

Participants from different disciplinary backgrounds suggested slightly varying roles that place of publication representation can have in helping users understand what books are about; specifically, they talked about bias, trust, and relevance. For instance, a participant from media studies made the assumption that if users can see that a local collection was published somewhere else, they might become biased about the quality of the collection (e.g., a user might think, "This was published in North America; the person knows nothing about Ukraine"). However, the participant of Slavic origin who was a bit more familiar with the content of Slavic literature and had a background in political science, took a different stand. She explained that different publications could be trusted based on the place of publication. For example, publications from the former Soviet Union would be less trustworthy than those published in North America. Books published in the former Soviet Union would be subject to certain ideological influences as compared to books published in North America. Therefore, information presented in books published in North America would be more objective compared to books published in the Soviet Union. Moreover, the level of trust might also depend on the period in which the book was published. Books on Japan published in the USA in the 1940s might have been much more biased and hostile than books published in the USA in the 1960s and'70s. In a joking manner, this participant suggested that books on the quality of life in the Soviet Union published in the Soviet Union were not to be trusted since the proponents of the Soviet ideology might paint too bright and subjective a picture of the quality of life. Instead one must look for books that were published outside the Soviet Union since these might be more objective. A participant with a background in linguistics commented that knowing the place of publication of a book might influence relevance judgement. She stated that knowing that an English book is actually published in Russia by Russians, one would likely not place it on one's high relevance list. Finally, two participants thought that such maps show who is publishing on this topic, and can, therefore, help users connect with others who are working on similar topics, build collaborative networks for research, and find publishers and universities they can contact.

Shortcomings in embedded maps noted by participants were similar to the ones identified for scatter plots. In particular, participants had the most trouble completing the visual counting tasks. Almost each participant made a mistake when counting items published within and outside of Ukraine. The problem seemed to stem from some overlaid and cluttered markers which were hard to discern without zooming into deeper layers of the map. In addition, dragging the embedded map was not always easy. It seemed to be more of a problem with Google, than a problem with the visualization application. Due to the difficulty with panning, participants often lost information windows. Such a problem could possibly be overcome by replacing tabbed information windows with overlays.

As to improvements, participants suggested adding a coordinated list of items or a table with locations, summarized by cities and countries and sorted by the number of publications, a pie chart, and possibly a timeline. In this way, users would have summaries in the table, on the map, on the pie chart, and on the timeline. All representations would be useful in this case. Other suggestions were related to representations on the map. A participant who had a background in geography preferred the idea of circles or bubbles instead of drop-shaped markers, because drop-shaped markers overlap and it is difficult to see what is behind them. Another participant noted that it is hard to see country borders, hence showing coloured polygons of the countries would help. Lastly, one user thought adding a search bar would help with navigation.

5.5.F Author Representations

Participants found author representations, in the form of tag clouds to be straightforward, useful, intuitive, easy, and suitable for facilitating understanding of collections. Nine participants thought that such representations can facilitate understanding; two did not think that they were representations at all, and said that they were just useful lists; and two said that they had difficulty with the author representations.

Those participants who found author clouds useful praised their font size, links, and alphabetical order for helping them understand the most prolific authors in collections for each location. Such representations were found particularly useful for novice users who knew nothing about Ukrainian history. One participant asserted that knowing that some authors have written multiple works might indicate that that they have done extensive research.

However, not all participants were satisfied with the author representations. Two participants referred to author representation tag clouds as just lists of authors, similar to text lists, which become difficult to make sense of when they are too long. Other participants complained that author representations were not aesthetically pleasing. One participant downplayed the role of author representations completely by commenting that from his point of view subjects were more important than authors. During the think-aloud session another participant consistently skipped over the author representations. He later explained this behaviour by stating: "I do not know; it is somewhat difficult. It was difficult; it looked more like a list. It did not really... in many many cases there were many authors who published only one book... I do not know maybe it needs some thinking to it? ... I think maybe because actual names were inaccessible to me? But yes, it is still useful to see..."

The larger the author tag clouds, the more overwhelming and difficult they seemed to be for study participants. Many participants simply could not remember any of the names from the tag clouds (because they were transliterated from Ukrainian and difficult to read), except for the names written in large font. One participant expressed a fear that for countries like Canada, such clouds may be too large and unusable. For these reasons, participants had difficulty identifying any trends in author representations. Participants only remembered the general size of the cloud and the number of significant authors the collection had.

Other shortcomings with author representations that participants identified included: 1. inflation of authors' representations due to duplicate copies of a book in the collection, 2. mixing of multiple alphabets and transliterations within a single list, and 3. limited ability to understand relationships among items in tag clouds (e.g., currently the visualization does not allow users to see all works of authors, only works written about specific locations).

Duplicate copies of a text within a collection might, for example, mislead users in their conclusions of who the most prolific authors are, since the representation simply inflates the font size of authors' names. The inclusion of author names transliterated from multiple languages in a single list might disorient users as to where to find some author names. For example, Russian or Ukrainian names starting with the letter "я" (which is found at the end of the Russian and Ukrainian alphabet) would be filed in the middle of the English alphabet under "ia". Separating tag clouds by language might alleviate this problem.

Finally, difficulty with understanding relationships between books and authors could possibly be overcome by linking other visual representations to author clouds, thus allowing users to explore such relationships in greater depth.

Participant suggestions for improving author representations included: indicating multiple copies of the same items; sorting authors by popularity, so that the most popular authors are listed close to the top (the example of Truman Capote was offered by one participant, as a writer who wrote only 3 books in his career, one of which is very popular; in this example, author popularity is more important than number of works by that author); adding other sorting capabilities that might add additional meaning to author clouds (e.g., sorting alphabetically or by number of copies).

Participants also discussed the utility of other representations for visualizing authors, namely timelines. Their opinion on timelines was split, with some participants favouring author timelines and others feeling they would not be effective. Those who liked timelines wanted to see years of publication on timelines, such that users would be allowed to see which books were written during different time periods, and which authors were published in the same time period, with additional information about the authors and their backgrounds. Those who disliked timelines thought that they might make things too complicated and were happy with author tag clouds. Other participants asked to see interaction between authors and subjects rather than time so that users could answer the question: what subjects did these authors write about?

5.6 Summary and Conclusions

This paper has presented VICOLEX, a visualization prototype intended to support sensemaking activities in the context of collection understanding. The focus of this paper has been to investigate how well dynamically generated additional representations in VICOLEX can support users' understanding of a georeferenced collection.

The additional representations used in VICOLEX include: (1) scatter plots that show book sizes and languages in collections; (2) pie charts that show languages in collections; (3) colour-coded histograms of years of publication that divide years of publication into different historical periods; (4) KMs that show subjects in collections; (5) embedded maps that show places of publication of collections; and (6) tag clouds that show lists of authors in collections.

A qualitative exploratory study of VICOLEX's representations was conducted using a think-aloud protocol, an interview, and a questionnaire in an experimental setting. The study was not conducted to test the usability of VICOLEX. Rather it was a study about a conceptual idea of using additional representations for representing collections. Although the sample size was not large enough to make conclusive statements about the general population, the study found that all participants thought that additional representations enhanced their understanding of collections. Furthermore, the findings of this study suggest that additional representations can support understanding of collections published in foreign languages. Although the insights of non-experts in Slavic languages and history may not be as good as expert users, the non-expert users were able to gain an understanding of the collection through interaction with the representations; the representations made them think and generate questions and hypotheses.

The study shows that each of the representations in VICOLEX supported and enhanced the participants' understanding of different aspects of collections, some in significant ways and others less so. Scatter plots informed users of the average size of the collection as well as oversized and extra small publications. Pie charts informed participants of the languages in the collections. Colour-coded histograms of years of publication helped users understand the history of disciplines as well as social, economic, and historical changes in locations. KMs helped users understand some trends in subjects in the collections of different locations. Embedded maps of places of publication helped users identify the locations of publishers, authors, and collaborators, and learn something about the flow of immigration. The tag clouds of author lists informed users about the most prolific authors in the collection.

This research suggests that additional representations linked to locations can enhance exploration and discovery of different aspects of library collections. Although this study cannot generalize beyond the techniques and the topic it examined, it suggests that additional representations can improve understanding of georeferenced collections. Perhaps the most important conclusion drawn from this study is that different representations support and enhance different mental activities. This study suggests that, when given different visual representations of data, users will use them to engage in exploration, hypothesis generation, and reasoning about different aspects of the underlying collections, their locations, and the representations themselves. These types of sensemaking activities need different external support structures and processes, which must be provided by map-based visualizations of library collections. Combined and integrated together, the additional representations generated from knowledge organization systems can allow users to not only explore and understand the structure and properties of collections, which are otherwise not visible in catalogues and simple map-based visualizations, but also make inferences and develop an understanding of the geographic locations the collections are about. Moreover, additional representations make geographic knowledge visible not only to expert users, but also novice users, including users who do not understand the language of the collection. Further research is needed in long-term studies to determine the effectiveness of VICOLEX for visualizing other types of collections.

5.7 References

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Chapter 6: Conclusions, Contributions, and Future Work

6.1 Geospatial Access

The research about georeferencing document collections started many years ago (see history in Buchel & Hill, 2009). Throughout these years many researchers in library and information science and geovisualization have been working on the conceptualization of geodigital libraries (libraries that use digital maps as front ends to their collections) (Buckland & Lancaster, 2004; Buckland, Gey, & Larson, 2004; Buckland, Chen, Gey, Larson, Mostern, & Petras, 2007; Hill, Buchel, Janee, & Zeng, 2002; Hill, 1990; Hill, 2006; Larson, 1996; Fabrikant & Buttenfield, 1997; Fabrikant & Buttenfield, 2001). However, the importance of their work has not always been understood by many other librarians and researchers because many first-generation map-based interfaces were not easy to interpret, understand or make sense of. The underlying reason for this is that map-based interfaces have emerged from print maps, geospatial technologies, and library catalogues. These technologies have helped researchers solve many issues related to geographic information retrieval, but they failed to inform researchers how to design maps that could help users make sense of information organized behind maps.

However, after Google released Google Maps API, we have been witnessing the emergence of a wide variety of map-based interfaces and map mashups, because Google Maps have significantly simplified the development of map-based interfaces. Today, RSS files and Dublin Core metadata records can be assigned geographic coordinates automatically and mapped on Google Maps in a short period of time. Many libraries are mapping their own collections on Google Maps. However, Google has not solved the problem of sensemaking by letting people put markers on the maps. The more markers we add to maps the harder they become to understand. For this reason, it was very important to find a solution for making sense of document collections linked to maps.

This dissertation has attempted to fill this gap by conceptualizing some ideas and developing a methodology for the design of map-based visualizations for sensemaking. The key premise of the dissertation is that the designers of map-based visualizations should take advantage of the information visualization techniques and interactions and use them to support users' sensemaking activities. Not only the dissertation presented the methodology for design but also explained how all components work together in the system — the high-fidelity prototype VICOLEX — that was built for this dissertation. Map-based visualizations like VICOLEX can enhance understanding of collections and locations associated with those collections. Such tools can enhance not only retrieval but also hypothesis generation, trend identification, and many other creative knowledge-generating activities.

This dissertation has also reinforced the importance of georeferencing (assignment of coordinates and footprints to placenames) since map-based visualizations cannot be built without formal georeferencing (i.e., without coordinates or geospatial footprints). But at the same time map-based visualizations complement georeferences by adding contextual meaning to them and to activities with them in the geographic space. Interactions help users notice trends, patterns, transitions, and associations in document collections that are hard to notice on static maps. Lastly, our exploration of the role of interactions identified reasons to explain why georeferencing text collections is important and how georeferences can enhance understanding of collections. By adding georeferences to text collections and visualizing them, we can make collections communicate information that was not visible before. A collection of text documents here is defined broadly as a collection of any full-text documents or electronic records including health records, archival records, real estate listings, ecommerce listings, or other records.

6.2 Research Contributions and Conclusions

This dissertation has developed two conceptualizations to guide the design of map-based visualizations as tools for sensemaking.

Conceptualization about additional representations, ontological properties, and visual tasks. Chapter 3 presented a conceptualization of library collections on map-based visualizations. The conceptualization explicated the need to support visual tasks that would facilitate gaining insight into ontological properties of collections linked to maps. It explained the role of additional representations of ontological properties of collections in the visual tasks. Additional representations help users understand trends and patterns in subjects, languages, book sizes, places of publication, years of publication, and authors in various geographic locations.

Conceptualization of sensemaking activities. Chapter 4 conceptualized sensemaking activities. Users often engage in such activities when they interact with geospatial information, especially when they need to understand a large number of markers linked to maps. Even though a large number of frameworks for analyzing sensemaking activities already exists (see, e.g., Gotz, 2007; Furnas & Russel, 2005; Qu & Furnas, 2005; Russel, Jeffries, & Irani, 2008; Russel, Stefik, Pirolli, & Card, 1993), it is difficult to get clear-cut answers about possible tasks and interactions from them – they are all high-level frameworks. Similarly difficult is to obtain information about potential tasks and subtasks by means of traditional methodological tools such as ethnographic interviews and semi-structured interviews, simply because many users have problems imagining the complexity of tasks and activities possible to complete with map-based visualizations. Instead of building on existing frameworks and user studies, our conceptualization is grounded on evidence from the human-computer interaction literature. The advantage of this approach is in the scope and breadth of coverage.

According to the conceptualization of sensemaking, activities are viewed as the high-level activities undertaken by users. Activities include tasks. Tasks are goal-oriented processes with representations. Tasks are composed of interactions. Interactions refer to the low-level actions that users perform on objects in order to complete tasks and activities. Interactions enable different properties, elements, relations, and layers of static visualizations to be probed, and made explicit and available on demand, thereby making the information better suited to the individual and contextual needs of users. The contribution of the dissertation is in explaining the role of interactions in understanding and making sense of the collections linked to map-based visualizations. Most importantly, the dissertation explains the role of these interactions not in isolation, but in coordination with each other. Interactions are explained, elaborated and illustrated on the example of VICOLEX — the visualization prototype.

The efficiency of the *Conceptualization about additional representations, ontological properties, and visual tasks* to describe a cognitively-complex, open-ended, and real-world activity was explored in Chapter 5 through a qualitative and exploratory study of collection understanding combined with the usability evaluation of representations. The results of the exploratory study show that the additional representations can enhance understanding of the structure of collections. This suggests that the conceptualization can be used for representing other digital collections and their properties (e.g., health records, real estate records, observations and so on). The results of the study show that representations can support collection understanding but not equally well: some representations are better than the others. For example, while pie charts, histograms, scatter plots, and maps of places of publication are easy to understand and identify patterns and trends; tag clouds and Kohonen maps require improvements. The study also shows that trends and patterns identified in the study are pertinent not only to collections but also to socio-economic processes in geographic locations.

6.3 Significance for Libraries

The proposed conceptualizations are important for various collections of documents, and especially libraries and archives. Today when libraries are facing budget cuts and closures, they should think about visualization of their collections. In catalogues map-based visualizations can be merged with other representations. For example, collections without geographic aspects can be shown on Kohonen Maps, or other abstract representations. Navigating through catalogues, users will have to switch between map-based visualizations and abstract representations. Such visualizations can make library catalogues engaging. They can help libraries attract wider audiences of users, draw attention to their collections, and educate patrons about their collections.

6.4 Future Work

Through these conceptualizations and illustrations, this dissertation has sought to develop a strategy for the design of map-based visualizations for geodigital libraries. Since it laid out only a foundation for interaction research in geodigital libraries, many other venues have to be investigated in the future. Some of these venues are described below.

6.4.1 Evaluation of Interactions

To ensure that the conceptualizations are effective and useful, they have to be thoroughly tested in controlled studies. However, as was explained in Chapter 5, the design of controlled experiments is associated with a number of problems related to measuring the outcomes of the higher level cognitive activities (Plaisant, 2004; Shneiderman & Plaisant, 2006; Mirel, 2007; Slaney & Russel, 2005). First of all, this is because tasks in higher-level cognitive activities are ill-defined. They are characterized by: vague or broad goals; large volumes of data; nonlinear, often uncharted analytical paths; no pre-set entry or stopping points; “good enough” solutions with no one right answer; and underlying patterns structuring open-ended investigations that are never performed the same way twice (Mirel, 2007). Controlled studies cannot measure the outcomes of such ill-defined activities. Controlled studies require constrained tasks, which can hardly capture all activities in ill-defined situations. In addition, controlling for individual differences in controlled studies of sensemaking activities may be nearly impossible.

Second, it is not easy to find the right users for such visualizations, since users should be experts in their knowledge domains. They need to be able to assign meaning to patterns that they discover in the visualization. They also should be able to evaluate patterns (i.e., judge their validity, relevancy, credibility, plausibility, and manageability) (Mirel, 2007). Patterns themselves have no inherent meaning; to be understood, patterns need to be interpreted (Stonier, 1990; Sedig, K. & Parsons, P., submitted). For instance, patterns that exist in VICOLEX have no meaning until they are interpreted in relation to the socio-economic context in Ukraine.

Nonetheless, some alternatives to controlled studies already exist (e.g., Multi-dimensional In-depth Long-term Case studies (MILCs)). The MILC paradigm builds on the notion of field or case studies using ethnographical participant observation methods, along with interviews, surveys, and automated logging of user activity. Promoters of the MILC method suggest long-term observations over weeks or months are necessary to fully understand how domain experts work and how they apply creativity support tools (Shneiderman, et al., 2006). Such a multiplicity of methods can provide multiple perspectives on tool usage. “This strategy seems to be the best hope for creating a compelling case for validity and generality” (Shneiderman & Plaisant, 2006, p. 43). The outcome may be specific suggestions for tool improvements and better understanding of design principles.

6.4.2 Other Activities

There is also a need to study other activities in digital libraries. This research should explore how people coordinate different interactions during the activities and develop ways to evaluate the effectiveness of these different coordination patterns. But activities should be analyzed regardless of technologies that people use. For example, recently in the library and information science literature there was a big discussion about serendipitous discoveries. Researchers have conducted several empirical studies that investigate various aspects of serendipitous discoveries (Toms, 2000; Thudt, Hinrichs, & Carpendale, 2011). However, technologies that were directly or indirectly involved in the studies highly constrained the outcomes of the studies. Toms (2000), for instance, considered interactions with a hyperlinked newspaper enhanced with a dynamic list of suggested articles. She found in this study that serendipitous discoveries can be stimulated and triggered by navigating the links to suggested articles. While this finding is plausible, the study has largely overlooked many other interactions that might be relevant to serendipitous discoveries (e.g., translating, selecting, grouping, classifying, and many others). There is a large body of evidence in HCI literature suggesting that there are many other interactions that can support chance discoveries. The research has to be conducted to collect all these interactions and understand their role in serendipitous discoveries.

Also additional research has to be done on investigating space appropriating and knowledge constructing activities. As Chapter 4 explained, when people work with information, they actively modify their working spaces. They use sticky notes, clippers, or space arrangements to create cues, constraints, and triggers which can tell them that only certain affordances are present, and only certain actions can be performed on those objects. Such spatial arrangements, cues and constraints reduce the cost of visual search, and make it easier to notice, identify and remember items in sensemaking, information foraging, and exploration (Kirsh, 1995). In VICOLEX we identified that people can create structures by annotating, selecting, and grouping. Currently all these constructs are temporary, suitable to support only short-term goals. One research goal would be investigating other structures people create when working with information from digital libraries, relating those structures to interactions and their epistemic benefits, and determining the lifespan of structures.

In Chapter 4 we also briefly discussed the importance of social spaces. However, we did not discuss the structure of social spaces, interactions in social spaces, and the interrelationship between social spaces and working spaces. Social spaces would benefit from a more systematic treatment. One important research direction along these lines is to investigate how map-based visualizations can support collaborative work. Collaboration would involve activities whereby people interact with representations of semantic and geographic spaces, as well as with each other. Besides analyzing the collaborative activities, it is also important to investigate the structure of social spaces and how collaborative interactions among users may transform the structure of social spaces.

6.4.3 Ontological Properties

This dissertation defined the structure of the Local History of Ukraine collection. Other collections might have different structures due to the peculiarities of their descriptions in bibliographic records. While many collections have structures similar to the structure of the Local History of Ukraine collection, other collections might be very different (Buchel, 2006). An example of an absolutely different collection is a collection of periodical literature. Unlike collections of books, periodicals have multiple volumes that add another temporal dimension. Such an ontological structure requires new additional representations and interactions.

But besides bibliographic descriptions some collections have additional datasets that contain ontologies of objects investigated in research papers. Such datasets, for example, can be found in social sciences collections, biodiversity collections, and many other collections. The descriptions of these objects are ontological; they describe properties of objects in the real world. To help users understand spatial distribution of such collections, librarians often show locations of objects described in papers on digital maps without paying any attention to the properties of objects. But these can be visualized with additional representations that can help users make better sense about objects described in papers. They can help users do meta-analyses of collections and discover patterns and trends that are otherwise inaccessible.

6.4.4 Other Dimensions of Interaction

Besides map-based visualizations, geographic aspect becomes more and more important in smartphone applications. Map applications help people navigate and find directions in real physical space (Rehrl, Göll, Leitinger, & Bruntsch, 2005), construct concept maps of visited places (Imbe, Ozaki, Kiyasu, Mizukami, et al., 2010), improve information retrieval, enhance social navigation (Bilandzic, Foth, & De Luca, 2008), interact with physical objects from a distance (e.g., location-based notification services), and adapt to new situations (Reichenbacher, 2004). In addition, smartphone applications provide many external aids that amplify users' cognitive abilities, shape their thinking processes, and enhance their understanding of information in the surrounding world (Satyanarayanan, 2011). Information in this context refers to the "pattern of organization of matter and energy" (Bates, 2005). Patterns can be observed in such things as cities, landscapes, infrared radiation, organisms, and so on. While not all patterns can be observed without augmenting the reality due to the scale at which they can be observed, many smartphone applications help people gain insight at patterns of various scales by transforming and augmenting these patterns in various ways (e.g., aggregating, abstracting, re-representing, transforming, etc.). This opens up a whole new dimension for interaction with various forms of information (not only text information). How can all these new interactions impact human cognition, reasoning, problem solving, sensemaking and other cognitive activities in space? What implications do these interactions have for the design of new applications? How can they transform human cognitive activities? All these questions I hope to tackle some of these questions in future the research.

6.5 Conclusion

The second generation geographic information systems such as Google Maps, Google Earth, Bing Maps, Open Street, and other digital map API services allowed developing mashups and visualizations that have led to dramatic changes in how we perceive georeferenced information and integrate it into our everyday lives. These geographic information systems also open up new possibilities for gaining new insights into georeferenced information. This dissertation has attempted to generate a strategy to explore some of these possibilities through conceptualizations. By synthesizing and integrating a range of research relevant to work with maps, text, and other forms of representation, these conceptualizations provide a starting point for describing complex sensemaking activities with information on the surface of digital maps, and show how representations and interactions with representations can be coordinated in complex activities. Maps designed with such conceptualizations can be used to help us better explore, analyze, reason with, learn from, and make sense of information. This dissertation has laid out a strategy for modeling new tasks and activities with different kinds of non-cartographic text-based information linked to map-based visualizations. In addition, it showed numerous ways in which these conceptualizations could be elaborated and further researched.

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Appendix A

The research tool VICOLEX (Visual COLlection EXplorer) has been developed for concept testing of the theoretical conceptualizations. It is a high-fidelity prototype, which visualizes MARC records from the Library of Congress Catalog. Its purpose is to serve as a communication device between the designers and the potential users for eliciting usability criteria from potential users, clarifying the requirements and tasks of the visualization, and testing out the technical feasibility of visualization concepts. The remaining part of this chapter describes the testbed collection, explains details about visualization of the testbed collection - representations and interactions.

Testbed Collection

VICOLEX visualizes the testbed collection which includes 349 MARC visualized records (and 6 suppressed records) from the Library of Congress catalogue with call numbers starting with DK508. All records in this collection have the same subject — "Local History and Description of Ukraine." The DK508 class in the collection has many subclasses (e.g., DK508.922, DK508.95.O33, and other); each subclass has references to geographic locations in Ukraine. For example, the subclasses DK508.922-DK508.939 are assigned to documents about Kiev; the subclass DK508.95.L86 is assigned to documents about L'viv; and the class DK508.95.O33 is assigned to documents about Odessa. Overall, the testbed collection has full collections of MARC records for 32 Ukrainian cities that existed in the catalogue before summer 2007 (when the testbed collection was built). In the dissertation these collections are often referred to as subcollections. The numbers of MARC records linked to the subcollections range from a few records to almost a hundred.

The records in the testbed collection contain only the key ontological properties: physical descriptions (illustrations, maps, height of the book, number of pages in the book, year of publication, place of publication), languages, types of publication, bibliographic notes, subjects, titles, call numbers, and acquisition numbers. Although the acquisition numbers do not carry ontological information since they are mostly used for accounting purposes in libraries; in our testbed collection they are used for identifying acquisition years of documents. All records were downloaded into 4 tables in the *bibliographic_records* database in MySQL. The main table — *bibliographic_record* — contains bibliographic information. Additional tables describe authors and subjects. The *call_numbers* table links classification numbers with geographical places described in the gazetteer. Relationships between tables are shown in Figure 1.

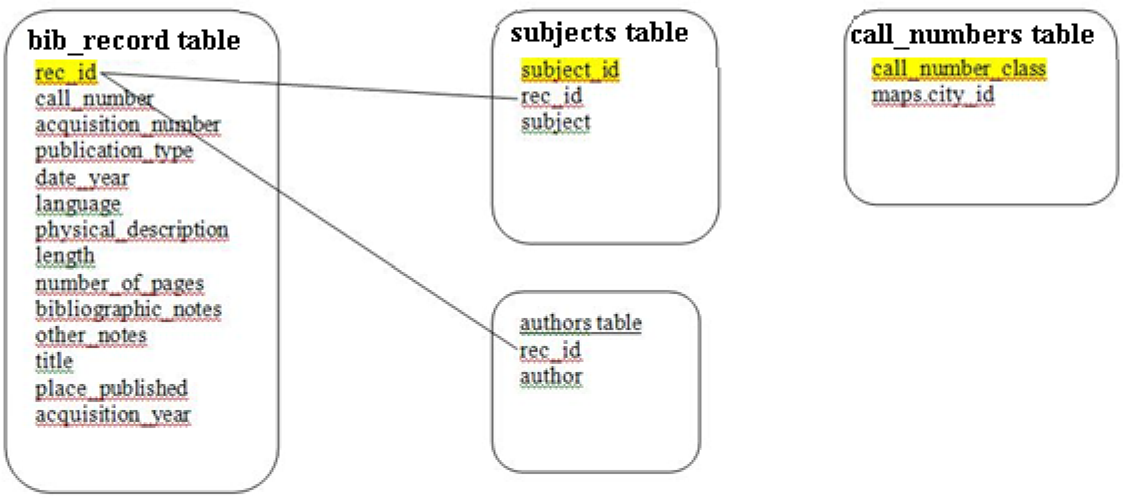


Figure 1 Tables containing bibliographic information.

After the data was collected, the testbed collection was inspected for potential parsing problems. For example, a problem was identified with book pagination, because documents often have mixed notation (in Arabic and Roman numerals):

> e.g.,
> 81 p., [8] p. of plates
> xviii, 204 p., [1] folded leaf of plates

Other problems were found with missing values. Fields that carry information about pagination (Machine Readable Cataloguing Field 300 |a) have more NULLs than any other fields. Moreover, instead of pagination, fields may carry information about the number of volumes instead of pages. Here are the examples of notation in the problematic records (problems are highlighted):

v. <1> : **|b** ill. ; **|c** 17 cm. (DK508.935 **|b** .V68 2002)
v. <1-6> : ill., maps ; 17 cm. (DK508.935 **|b** .K68 2002)
2 v. : ill. (some col.) ; 20 cm. (DK508.934.K67 A3 1998)
v. <1-2 > ; 20 cm. (DK508.933 .K96 1997)

VICOLEX currently suppresses these problematic records from visualization (6 records total), since they may cause problems for representations. Missing values in visualizations are not uncommon. For instance, Ahonen-Rainio (2005) reported that she had missing values in geospatial metadata and had to assign some special codes to the problematic items to make them visible on the display.

Besides documents, VICOLEX also has descriptions of ontological properties of geographic locations. These properties are recorded in the gazetteer that has a schema separate from the *bibliographic_records* database. The gazetteer plays the role of a dictionary that translates call numbers in the bibliographic records to both direct and indirect georeferences (i.e., text and coordinates). While, georeferences in text facilitate text retrieval, coordinates are required for putting documents on a map. Although the translation between text and coordinates could be facilitated by Google Maps API, it was not considered to be the best solution for VICOLEX for the following reasons. First of all, loading from Google Maps takes longer than from the gazetteer stored on a local server. Second, the custom-made gazetteer enabled more customized descriptions for locations. For example, the VICOLEX gazetteer has variant spellings of geographic locations, images of flags or coats of arms, footprint information (latitude and longitude), and some additional information such as population sizes, feature types, and some references with links. The gazetteer was built from three sources: Google Maps, Alexandria Digital Library gazetteer, and Wikipedia. The gazetteer has only one table *placenames*, the structure of which is shown in the Figure 2.

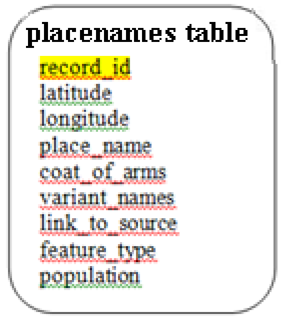


Figure 2 Gazetteer table.

Visualization

VICOLEX is designed with close attention to representations and interactions with the purpose of making collection structure more salient; providing users with multiple perspectives on the data. Representations show the collection and its subcollections from different perspectives. Interactions serve as glue that links all representations, facilitate navigation among them, and allow modifying ontological properties according to users' needs. Representations and interactions are discussed in greater detail below.

Representations

As to representations, a variety of different representations was chosen. Each representation represents a collection or a sub-collection from a different perspective. More specifically, all metadata records are mapped onto Google Maps (GM) (see Figure 3 below). Each marker of GM represents the number of metadata records in each sub-collection. Since some collections for individual locations have quite a large number of records (e.g., Odessa – 50, Lviv – 78, Kyyiv – 92), additional graphical representations are used to represent ontological properties of sub-collections. Among representations chosen to encode ontological properties are scatter plots, pie charts, Kohonen maps, geographical maps, histograms, and tag clouds. An example is shown in Figure 3. The scatter plot is utilized for showing book heights, number of pages, and languages (Figure 3.a); the pie chart, for displaying languages

(Figure 3.b); the histogram, for showing years of publication (Figure 3.c); the embedded map, for visualizing places of publication (Figure 3.d); the Kohonen map, for representing subjects (Figure 3.e); and the tag cloud, for displaying authors (Figure 3.f).

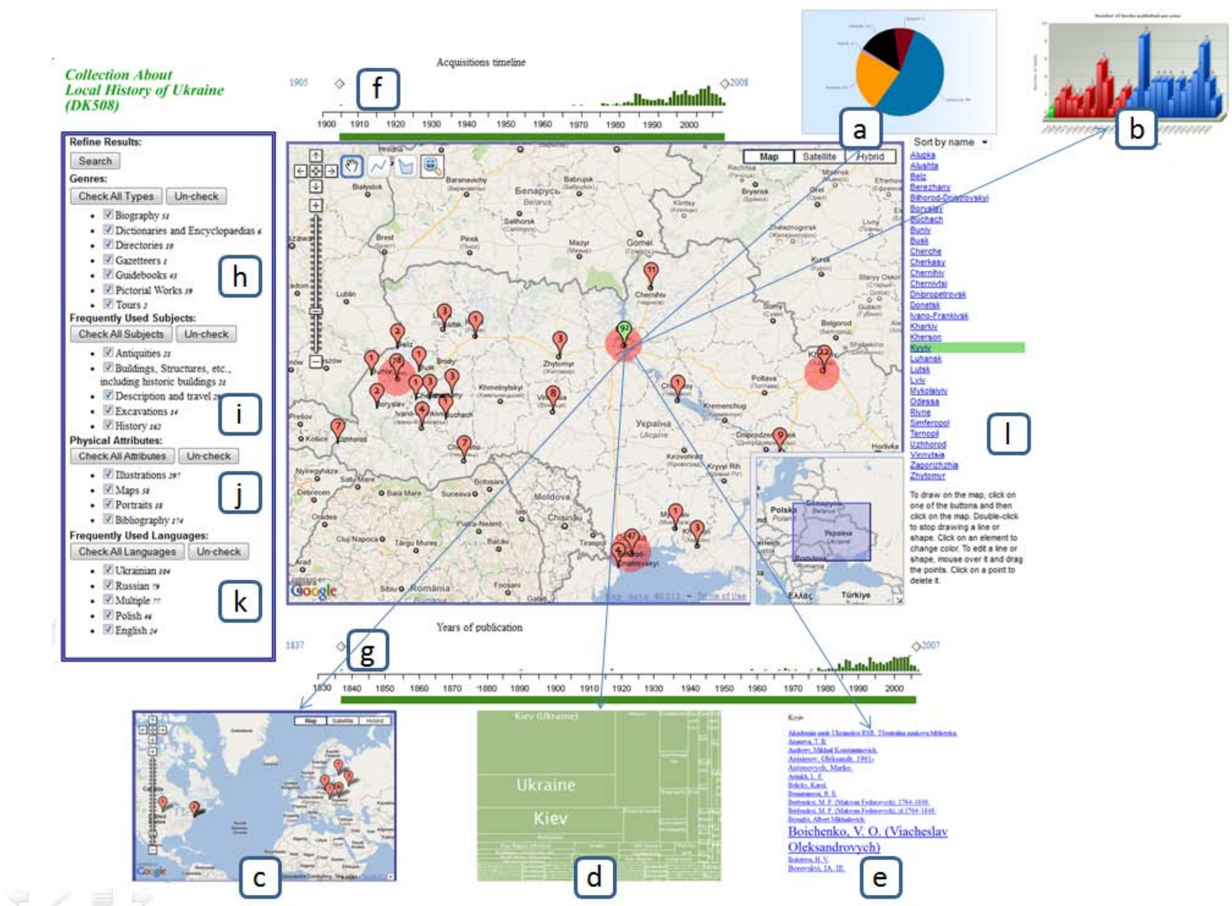


Figure 3 Representing collections on Google Maps. Each city on this map is linked to a number of graphical representations that show ontological properties of sub-collections. These representations are: a) the scatter plot of book sizes; b) the language pie chart; c) the histogram of years of publication; d) the embedded map with places of publication; e) the Kohonen map of subjects; f) the tag cloud with names of the authors.

Overall, VICOLEX has 193 representations. These representations encode the entities in the prototype collection (i.e., the sub-collections and the documents) and their properties. These representations help users gain insight into the various aspects of the collection which are hidden from view on the main map and are not perceptually-accessible by looking at the map. Each representation encodes only small portions of collection properties and answers only specific questions, hence making the main map in VICOLEX less cluttered. Some representations assign additional meaning to data (e.g., histogram of the years explains years of publication in terms of historical periods). Each set of representations for each location encodes storybooks about that sub-collection, related to subjects, years of publication, languages, book sizes, authors, and where the sub-collection was published.

VICOLEX is built with Google Maps API (application programming interface) Version 2.0 (a free web map server application provided by Google). Although ideas and principles outlined in this paper could have been implemented on other digital maps, GM were given preference because they already have many built-in functions and interactions. For example, users can zoom into various layers, focus onto geographical references at different levels of abstraction, navigate between different layers, and pan the map by dragging it to a new location. Moreover, the designers of GM API have addressed and resolved many previous problems with digital maps by adding new interactions and representations. For example, GM has a small global map in the corner for better navigation. The role of this global map is equivalent to a cognitive map that facilitates navigation in conceptual and physical space (Spence, 1999, 2007; Sedig, Rowhani, & Liang, 2005) and reveals information about the structure of space (Kearney & Kaplan, 1997). Before such global maps were introduced users often felt lost when zooming into the deeper layers of digital maps.

GM provides a support for many map mashups embedded in third party websites via the GM API[1] and Ajax. Ajax (Asynchronous JavasScript and XML) is a suite of technologies, based on one of the most popular scripting languages on the Web, XHTML and CSS, XSLT, XML, and JavaScript. Ajax provides the competitive advantage over other existing technologies by allowing the user's interaction with the application to happen asynchronously, minimizing the loading time of applications with embedded GM (Garret, 2005). Together GM API and Ajax allow the production of client-side scripts and the introduction of new representations and interactions into the GM interface. With the help of

[1] www.google.com/apis/maps/

Ajax, dynamic map attributes such as interactive legends, information windows for individual locations, customized navigational controls have become easier to develop than it has ever been possible before.

Other representations such as pie charts, histograms, and scatter plots were developed with open source Flash plugins available from Fusion Charts (http://www.fusioncharts.com/). Typically, such plugins are used as standalone components of dashboards, which are often used for visualizing business information. Although there are many other similar applications that can be embedded in visualizations (e.g., Many Eyes, Google Charts Tools), the preference was given to Fusion Charts because of their interactions. Fusion Charts applications, unlike other charts and graphs, allow raw data or other representations to be linked to various parts of charts and graphs. This allows creating visualizations with rich flow of interactions and representations, where representations change to other representations upon interaction.

All representations in VICOLEX are supported by data transformations in the database. Transformations are necessary for facilitating translation from one form of representation to another (e.g., from text to a table, or from the table to a graph or a chart). In VICOLEX such transformations are facilitated by the following queries: aggregation operations (such as Count, Group, and Join), sorting, filtering (in order to display only interesting ranges of data), and ordering. MySQL database, much like any other database, is an ideal tool for carrying out such transformations. It is optimized for performing such transformations and can be scaled to very large datasets. Attribute grouping, ordering, counting, joining tables together using a common key or set of keys are easily executed at the table level.

However, not all transformations can be achieved with queries alone. To avoid showing duplicated results, all results of intermediary queries are stored in VICOLEX in a temporary table (shown in Figure 4). The temporary table is a source of all representations. For example, when VICOLEX filters documents with Maps by Description and Travel subject, the results are retrieved with the Boolean operator OR and are stored in the temporary table. Then the representations send queries to the temporary table and ask about counts of various properties. Although the temporary table duplicates information stored in the main tables, it helps to filter out duplicates retrieved with the Boolean operator, and expedites the time and complexity of query processing in the prototype.

Figure 4 Temporary table.

Interactions

Although representations help reveal different properties and entities in the collection, they are not very efficient at communicating relationships among properties, and spatial and temporal distributions of discrete properties. To overcome these and other shortcomings, representations in VICOLEX are augmented with interactions, particularly the following ones: linking, filtering, comparing, selecting, and grouping. In the rest of this section, each interaction is explained in greater detail.

Linking. Linking allows users to establish a relationship between representations, especially between representations of locations on the map and representations which are associated with the locations. They define associations, and therefore help users better interpret represented information.

Filtering. Filtering allows users to sift out document properties. Users can query the ontological properties of a collection/sub-collection by Genres, Frequently Used Subjects, Physical Attributes, Frequently Used Languages, by Location Population Sizes, and by Time of Acquisition and Publication (shown in Figure 5). The results are combined with Boolean operator OR. Filtering by properties reduces the complexity of high-dimensional data, reduces cluttering that occurs when data points are displayed simultaneously, gives users flexibility in selecting properties, and generates a number of simple, easy-to-understand displays, each focused clearly on a particular aspect of the underlying data.

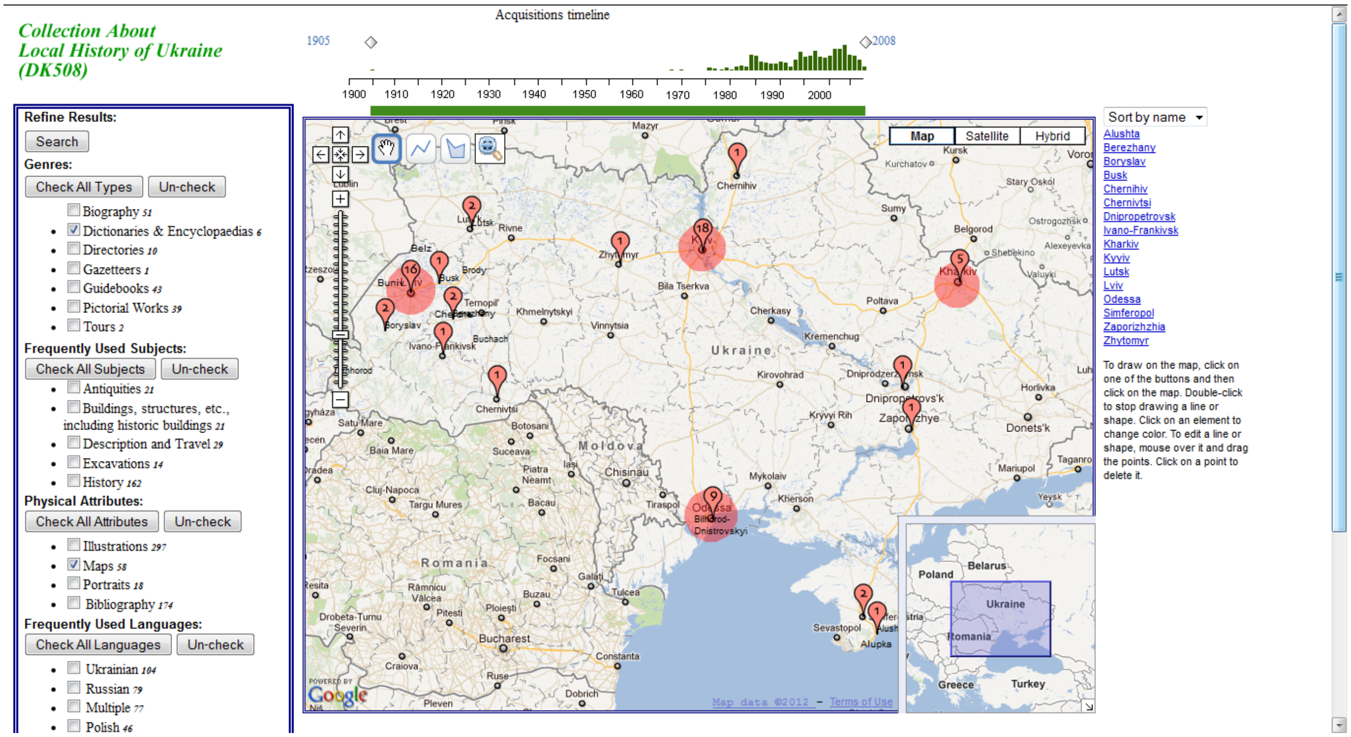
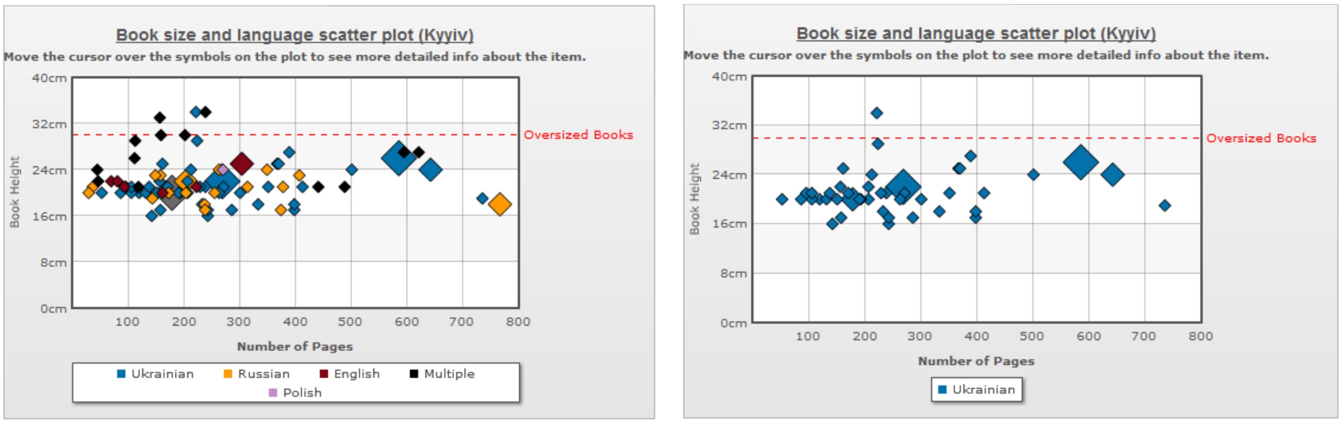


Figure 5 Filtering VICOLEX by genres and physical attributes.

In VICOLEX, the results of filtering can be observed not only on the surface of the map, but also on the representations of ontological properties of individual sub-collections that are linked to markers (Figure 6). Because of filtering on the map, the representations of ontological properties in these collections become more legible, less dense, and easier to understand. Such filtering allows completing tasks not only at the level of documents, but also at the level of properties; it makes properties much more salient.



a.

b.

Figure 6 Example of filtering by language: a) unfiltered book-size scatter plot of the entire sub-collection about Kiev; b) the same scatter plot filtered by the Ukrainian language.

Comparing. This interaction allows users to represent and arrange information elements, which are latent in the markers, in a table. These represented elements, which are displayed in the cells of the table, can then be compared side-by-side in rows. Such side-by-side comparisons are easier to accomplish than memory-based comparisons, because users are able to view concurrently the same aspects of different sub-collections.

Selecting. Selecting objects with certain properties from unnamed geographic areas (e.g., north or south of some region) from maps can be quite challenging because such regions are rarely described in systems explicitly. To facilitate this type of selection, VICOLEX allows selecting regions with markers by drawing a bounding box around markers with a drag-and-drop rectangle corner technique (Figure 7.b).

Such a selection can be performed both on an entire collection as well as on a filtered collection. For example, a user can make visible only books about history and select only those from the Western Ukraine using the bounding box (Figure 7.a and b). Properties that are suppressed by filtering cannot be selected with the bounding box. Moreover, the area selection mechanism in VICOLEX is coupled with grouping interaction which results in representing the selected documents with the same set of additional representations as documents that are linked to individual markers (Figure 7.c). Such selections with groupings can be useful for answering the following questions: a) In which area of Ukraine do collections have more illustrations? b) Are places of publication in collections about small locations different from places of publication about large locations? c) Is there a difference in subjects in collections about different parts of Ukraine? And other queries.

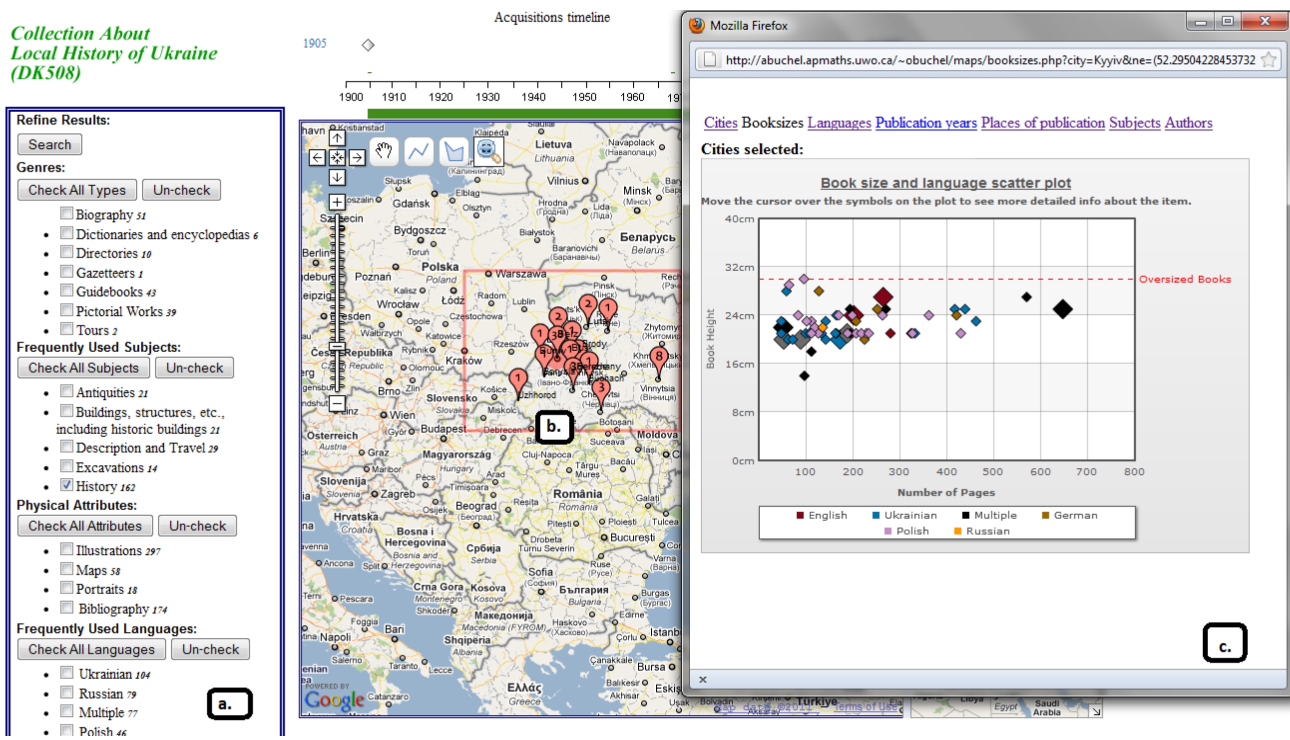


Figure 7 Example of selection with filtering and grouping. The collection was filtered by the subject “History” in the legend (a); then the markers from the Western Ukraine were selected with the bounding box (b); and then grouped together and represented on a scatterplot (c).

VICOLEX also facilitates more flexible selection and grouping with its geometry tools. Geometry tools allow users to draw various shapes and lines and measure their areas and distances. Information about distances and areas enhances users' understanding of unfamiliar spaces and places. Users can compare distances and areas to the ones that they already know.

Annotating. In VICOLEX annotating allows users to add personalized information and create user metadata. There are different kinds of annotations in VICOLEX: automated, structured, and free-text. Automated annotation is used to support the formation of cognitive maps as users move around the spaces and to enable them to retrace their walks if necessary. For this VICOLEX marks a user's footprints in an information space by changing the colour of visited markers. These visited markers act like electronic footprints to help users stay aware of what parts of the map they have already visited.

Another interesting feature of VICOLEX is that annotating footprints on the map is tightly coupled with annotating placenames in the sidebar. Figure 8 shows green markers on the map and green highlights in the sidebar which mark the user's path through the information space. The tight coupling technique that is used along with the annotations record user actions simultaneously in the sidebar and the map.

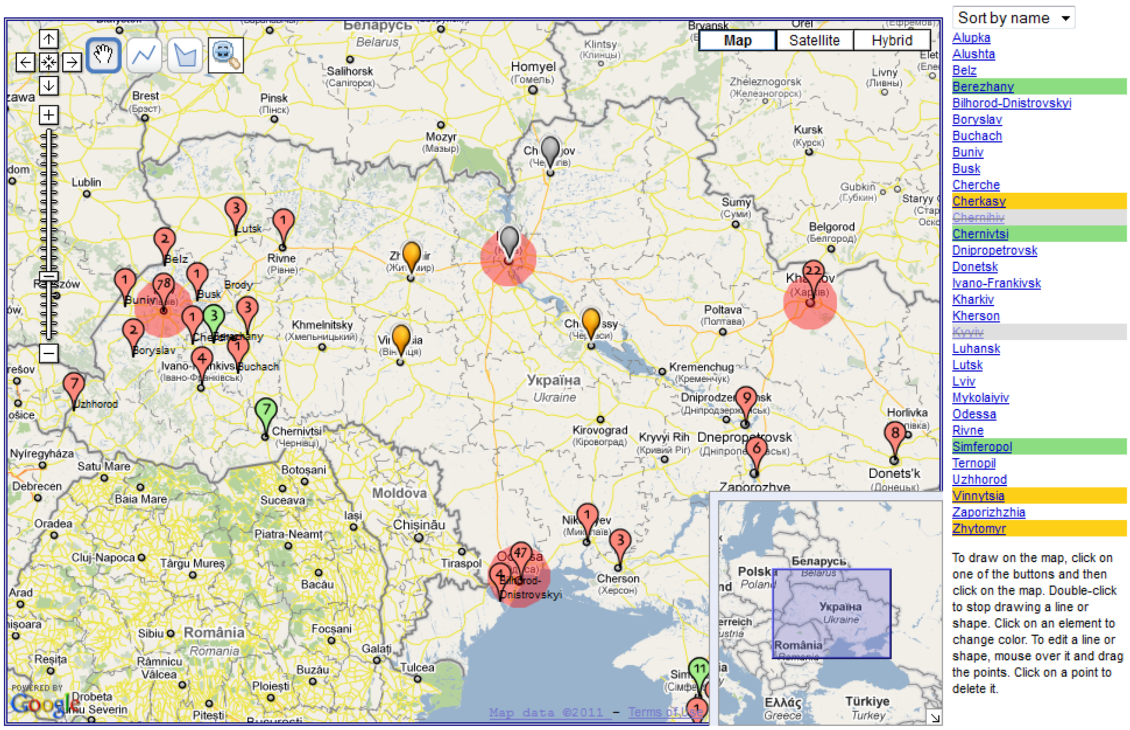


Figure 8 Annotating in VICOLEX: green markers and highlights in the sidebar mean that collections have been visited; gold markers and highlights mean that collections have been marked as special; gray markers and highlights with crossed-out text mean that collections have been marked as special; gray markers and highlights with crossed-out text mean that collections have been marked as irrelevant (discarded or suppressed).

Besides green markers and highlights, Figure 8 also shows gray and gold markers and highlights. Gray color means that a marker has been removed, and gold means that markers have been flagged as special. They are intended to function as place markers, triggers or cues, as a way of remembering. Triggers or cues help users in guiding future attention: they designate triggers to ignore or to revisit in the future. Changing the color of markers is an example of structured annotating. Such annotations consistently provide to users semantic and mnemonic information about relevant, irrelevant, and visited collections.

In addition, markers in VICOLEX support free-text annotations. They have no fixed vocabulary, no explicit relationship between annotation key phrases, and no specific structure.

These annotations generate user-created metadata that can capture user judgements, observations, opinions, problems, and solutions.

Annotating, comparing, linking, and filtering interactions in VICOLEX were developed with PHP 5.0 and Javascript. Open source plugins such as Google Maps Geometrycontrols and DragZoomControl (both available from gmaps-utility-library-dev at http://code.google.com/p/gmaps-utility-library-dev/) were used for developing selecting and measuring interactions. These plugins are available in public domain and are used extensively in Google Maps mashups.

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Appendix B

Collection Understanding Study Documents

Letter of Information

Measuring Collection Understanding in a Map-Based Visualization Prototype

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Letter of Information

Project Purpose

Thank you for taking an interest in our study. The purpose and objectives of this study are to investigate whether our map-based visualization prototype can enhance users' understanding of collections. Nowadays, facilitating rapid and insightful collection understanding is critical as it has never been before, when document collections are expanding exponentially.

If you agree to participate we will use screen and audio recordings, as well as interviewing, to explore your actions, reactions, and opinions as you use this new tool. Participants' insights regarding the effectiveness (or ineffectiveness) of the approach used in our prototype will be helpful.

Procedures

This study examines the utility of graphical representations such as pie charts, histograms, scatter plots, Kohonen Maps, and tag clouds linked to Google Maps in facilitating understanding of collections. As a participant, you will be asked to explore the representations in our prototype with the purpose of making sense about collections linked to Google Maps. For this activity no extensive prior experience with Google Maps is necessary; just an interest in information issues, information visualization, and geovisualization.

All your interactions and discussion of the representations will be recorded using screen capture video software and an audio recorder. This information will be transcribed for later analysis.

After the search process you will be asked about your understanding, insights, conclusions, and experience using representations. You will also be asked how useful you found the representations in facilitating rapid understanding of the collection.

The study will take approximately one hour and fifteen minutes. Approximately 10 participants are being recruited for this study.

At all times during the study, both the principal investigator and the student investigator will be available by phone or e-mail to address any questions about the procedures, and ensure that they are fully understood.

Confidentiality

Your demographic information will not be used to identify you. The identities of all participants will remain anonymous and will be kept confidential. In field notes and in reporting of the results, participants' identities are hidden through the use of numeric identifiers. With your consent, digital recordings and screenshots of your data will be taken and presented in such a way that they protect your identity. Any personal information will be stored securely in a password protected computer account accessible to only the principal and student investigator.

Dissemination

The findings collected from this study may be used in the student investigator's doctoral dissertation, academic conference/journal publications, presentations, and workshops.

Consent

We intend for your participation in this project to be pleasant and stress-free. There is no conflict of interest on the part of the researchers. Your participation is entirely voluntary and you may refuse to participate or withdraw from the study at any time.

The signing of the consent form acknowledges that you have received and read the project description. Keep a copy of this description of the study for your own reference and the consent slip attached.

Contact Information about the Project

If you have any questions or require further information about the project you may contact Olga Buchel ([redacted]) or Kamran Sedig ([redacted]). If you have any concerns about the project or your participation, you may contact:

Office of Research Ethics

Tel: [redacted]

Email: [redacted]

Consent Form

Measuring Collection Understanding in a Map-Based Visualization Prototype

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Phone: [redacted]
Fax: [redacted]
Email: [redacted]

Consent Form
I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction, and I understand that I may withdraw my participation at any time.

____
Participant's name

____
Participant's signature

____
Name of Person Obtaining Consent

____
Signature of Person Obtaining Consent

____
Date

Questionnaire

Measuring Collection Understanding in a Map-Based Visualization Prototype

Investigator: Olga Buchel (oburchel@uwo.ca)

1.	Gender	F	M			
2.	Age	___				
3.	Academic Background	______________________________				
4.	Professional Background	______________________________				
5.	Years using a computer?	___				
6.	Self-Rated Experience with computers (desktop, laptop)?	Novice		Intermediate		Expert
7.	Self-rated experience with statistical graphs and charts?	Novice		Intermediate		Expert
8.	Self-rated experience with information visualization representations (e.g., tag clouds, Kohonen Maps)?	Novice		Intermediate		Expert
9.	Use Google Maps or other digital maps?	Never	Rarely	Sometimes	Often	Frequently
10.	Self-rated experience with classifications and metadata?	Novice		Intermediate		Expert
11.	Self-rated experience with Local History of Ukraine Collections?	Novice		Intermediate		Expert

Western
Faculty of
Information and
Media Studies

Office of the Dean

Ethical Review of Research Involving Human Subjects

All non-medical research involving human subjects at the University of Western Ontario is carried out in compliance with the Social Sciences and Humanities Research Council Guidelines (2002). The Faculty of Information & Media Studies (FIMS) Research Committee has the mandate to review minimal risk research proposals for members of the FIMS community. Proposals are reviewed for adherence to the above guidelines.

2010 – 2011 FIMS Research Committee Membership

1. J. Burkell (alt)
2. G. Campbell
3. C. Farber*
4. H. Hill
5. V. Manzerolle
6. P. McKenzie* (Chair)
7. D. Neal
8. K. Sedig (alt)
9. C. Whippey
10. L. Xiao

Research Committee members marked with * have examined the research project **FIMS 2010-027** entitled:

Measuring Collection Understanding in a Map-Based Visualization Prototype

as submitted by: Kamran Sedig (Principal Investigator / Supervisor)
Olha Buchel (Co-investigator / Student)

and consider it to be acceptable on ethical grounds for research involving human subjects under the conditions of the University's Policy on Research Involving Human Subjects. Approval is given for the period **December 3, 2010 to April 30, 2011**.

Approval Date: December 3, 2010

[redacted]

FIMS Research Committee Chair

The **University** *of* **Western Ontario**
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VITA

Olga Buchel

EDUCATION

2004-Present (expected February 2012)

- PhD in Library and Information Science, Faculty of Information and media studies, University of Western Ontario

2001

- MS in Library and Information Science, Graduate School of Library and Information Science, University of Illinois at Urbana-Champaign, Ubrana-Champaign, IL

1994

- BA English and German (degree with "Highest distinction"), Department of Foreign Languages, Volyn State University, Lutsk, Ukraine

RESEARCH INTERESTS

Knowledge Organization

- Knowledge Organization Systems/Services; gazetteers; geospatial ontologies.

Information Visualization

- interactive map-based visualization of knowledge organization schemas; graphical representation of ontological properties of publications and classifications; knowledge discovery with graphical representations

Information Retrieval

- extraction techniques; retrieval tasks; geographic information retrieval; location-based queries

Human Computer Interaction

- usability; sensemaking; visual tasks; epistemic activities; dynamic queries; dynamic maps; geobrowsing; cognitive tools

GRANTS AND AWARDS

2011

- Graduate Thesis Research Award, University of Western Ontario

2004 – 2009

- Special University Scholarship (for the period of four years)

2004 – 2009

- University of Western Ontario Faculty Dependents' Tuition Scholarship award

2006

- Faculty of Information and Media Studies Travel Fund to attend the 'Knowledge Organization for a Global Learning Society' conference, July 5-7, 2006, in Vienna, Austria

2008

- Faculty of Information and Media Studies Travel Fund to attend ISKO conference, August 5-8, 2008, in Montreal, QC

2001

- LITA/Christian Larew Memorial Scholarship (one of two scholarships available to international students) awarded at LITA, ALA conference in San Francisco, June 2001

PROFESSIONAL EXPERIENCE

Instructional Designer, Faculty of Health and Rehabilitation Sciences, UWO □ July 2011– September 2011

- Purchased software for lecture presentations, video sharing, and synchronous teaching. Updated course websites in WebCT

- Helped with setting up synchronous learning environments

Software Consultant, Talsk Research, Inc., Chicago, IL □ July 2011– September 2011

- Evaluated a software, analyzed data flow, created a controlled vocabulary, conducted a user study, wrote a report about the study

Slavic Expert Consultant, Cyrillic OPAC, "Kalyna" Project, Queens Borough Public Library, Jamaica, NY □ Summer 2003

• Helped with the conversion of MARC records from Latin to Cyrillic glyphs

Translator, American Ukrainian Medical Project, http://uk.aump.org/home/index.php □ July 2011 – September 2011

• Translated and prepared for publication a brochure about autoclaves from English to Ukrainian

Research Associate, ADEPT, Alexandria Digital Library Prototype Project, NSF-Digital Library Initiative 2, Department of Computer Science, University of California at Santa Barbara, CA □ August 2001– March 2003

• Developed Knowledge Base and self-organizing concept/topic maps for undergraduate students studying physical geography; developed ADEPT Catalog, using ADEPT/DLESE/NASA metadata standard; cataloged learning objects, mainly images

• Built controlled vocabularies for physical geography class

Intern, ADEPT, Alexandria Digital Library Prototype Project, NSF-Digital Library Initiative 2, Department of Computer Science, University of California at Santa Barbara, CA □ January 2001– May 2001

• Developed ADEPT Selector, a catalog for learning materials

Intern, Collection Development Department, University of California at Santa Barbara, Santa Barbara, CA □ January 2001– May 2001

• Updated Information Sources for Eastern European Studies website, an online reference guide for library patrons

Slavic Serials Assistant, Central Technical Services, Cornell University Libraries, Ithaca, NY, USA □ March 1998– August 1999

• Performed pre-order searching in RLIN, OCLC and NOTIS; placed on-line orders, claimed missing and overdue issues for serial titles; created bibliographic records in NOTIS using USMARC, AACRII, and CUL standard guidelines

TEACHING EXPERIENCE

Limited Duties Instructor, Faculty of Information and Media Studies, University of Western Ontario, London, ON □ Summer 2010, Fall 2011

• Taught Geodigital Libraries Class. Responsible for designing curriculum, lecturing, conducting labs, holding office hours and assigning grades

Graduate Teaching Assistant, Faculty of Information and Media Studies, University of Western Ontario, London, ON □ September 2004– December 2010

• Coordinated labs with lectures, designed and graded labs, assignments, and exams, maintained web sites in WebCT for a variety of graduate and undergraduate classes, including Research methods, Information Systems and Technology, Information and its Contexts, Introduction to Information Retrieval, The Matter of Technology, The Meaning of Technology: Exploring the Relationship Between Technology and Society

FUNDED RESEARCH EXPERIENCE

Graduate Researh Assistant, Faculty of Information and Media Studies, University of Western Ontario, London, ON □ January 2009– May 2009

• Designed forms and a database in MS Access; installed Linux, Apache, and PHP on a server; conducted semantic analysis of collected data; designed a software program for harvesting and parsing RSS files

Team: Dr. Victoria Rubin and Language and Information Technologies Research Lab

Programmer, VPR funded project Cataloging Models For Geosciences, SIRL, University of Arizona at Tucson □ January 2002– June 2002

• Developed a research tool for cataloging models and worked on the classification schema for cataloging hydrology models

Team: Dr. Anita Coleman

Library Assistant III, Collection Management Initiative project (http://www.ucop.edu/cmi/welcome.html), the University of California systemwide research project on usage of digital and print versions of selected journal titles funded by the Andrew W. Mellon Foundation, Library Administration Department, University of California at Santa Barbara, CA □ June 2001– August 2001

• Developed a program in C++ for automated parsing of serials MARC records for downloading them into a project database and later analyzing their usage

Library Assistant II, Technical Services Cost Study project
(http://www.arl.org/stats/newmeas/tcs_overview.html), Library Administration Department, University of California at Santa Barbara, CA □ June 2001 – August 2001

- Processed and analyzed sample data collected from technical services about productivity, tasks and associated costs over the period of time from 1998-2001. Completed comparisons of data between participating in the cost study libraries Cornell, Iowa State, Vanderbilt, and UCSB

PUBLICATIONS

Refereed Publications

Buchel, O., & Sedig, K. (in preparation). “Can additional representations in map-based visualizations enhance sensemaking activities such as collection understanding?”

Buchel, O., & Sedig, K. (r&r to Information Research journal). “Making Sense of Document Collections with Map-Based Visualizations: Interacting with Representations.”

Buchel, O., Sedig, K. (2011). “Extending Map-Based Visualizations to Support Visual Tasks: The Role of Ontological Properties.” Knowledge Organization Journal 38(3), 204-230.

Buchel, O., Hill, L. (2009). “Treatment of georeferencing in Knowledge Organization Systems: North American Contributions to Integrated georeferencing.” North American Symposium on Knowledge Organization (NASKO). Syracuse, NY. This paper was selected for publication in Knowledge Organization (Special Issue: The Best of NASKO 2009) as one of the best papers at NASKO.

Buchel, O., Coleman, A. (2003). “How Can Classificatory Structures be Used to Improve Science Education?” Library Resources and Technical Services 47(1).

Book Sections

Buchel, O. (r&r) “Designing and Visualizing Faceted Geospatial Ontologies from Library Knowledge Organization Systems.” In Neal, D. “Indexing and Retrieval of Non-Text Information.”

Conference Proceedings

Buchel, O., Sedig, K. (2011). “Using Map-Based Visual Interfaces to Facilitate Knowledge Discovery in Digital Libraries.” ASIST Proceedings 2011.

Buchel, O. (2011). “Designing Map-Based Visualizations for Collection Understanding.” Proceedings of JCDL 2011.

Buchel, O. (2006). “Uncovering Hidden Clues about Geographic Visualization in LCC.” Ninth International Society for Knowledge Organization Conference “Knowledge Organization for a Global Learning Society,” Vienna, Austria.

Smith, T. S., Ancona D., Buchel O.A., Freeston M., Heller W., Nottrott R., Tierney T., and Ushakov A. (2003). “The ADEPT Concept-Based Digital Learning Environment.” 7th ECDL 2003, Trondheim, Norway, Springer-Verlag.

Smith, T. R., Zeng, M.L., Agapova, O., Buchel, O.A., Freeston, M., Frew, J., Hill, L.L., Smart, L., Tierney, T., Ushakov, A. (2002). “Structured Models of Scientific Concepts for Organizing, Accessing, and Using Learning Materials.” Joint Conference on Digital Libraries 2002 (JCDL 2002), Portland, Oregon.

Hill, L. L., Buchel, O., Janée, G., and Zeng, M. L. (2002). “Integration of Knowledge Organization Systems into Digital Library Architectures: Position Paper.” Advances in Classification Research. Proceedings of the 13th ASIST SIG/CR Workshop on "Reconceptualising Classification Research," Philadelphia, PA.

Coleman, A., Smith, T.R., Buchel, O.A., and Mayer, R.E. (2001). “Learning Spaces in Digital Libraries.” 5th European Conference on Advanced Research and Technology for Digital Libraries, Darmstadt, Germany, Springer-Verlag.

Junior Thesis

Buchel, O. (1994) “Thesis: Integrity And Discretion - the Cardinal Properties of a Text (on the example of S. Maugham’s novels).” Unpublished Senior Thesis, Volyn State University.

PRESENTATIONS

October 9, 2011

- Using Map-Based Visual Interfaces to Facilitate Knowledge Discovery in Digital Libraries, ASIST Annual Meeting - 2011, Ottawa (poster presentation)

June 14, 2011

- Designing Map-Based Visualizations for Collection Understanding, Joint Conference on Digital Libraries, Ottawa (poster presentation)

May 22, 2011

- Interactive Map-Based Visualizations & Sensemaking, THATCamp: The Humanities and Technology Camp, University of western Ontario, http://2011.thatcampuwo.org/

March 28, 2011

- “Spatial Information.” MLIS 9852: Images, Music, and Video: Non-text Information, Dr. Diane Neal, instructor, Faculty of Information and Media studies, University of Western Ontario

June 16, 2010

- Visualizing Library Collections for Sensemaking. Joint conference of the Association of Canadian Map Libraries and Archives (ACMLA/ACACC) Canadian Association of Public Data Users (CAPDU). Guelph, ON: University of Guelph.

May 16, 2010

- The role of working space representation and epistemic interactions in map-based visualizations. Connections 2010. London, ON: University of Western Ontario

March 24, 2010

- Crystallizing Knowledge About Library Collections. FIMS/Faculty of Arts and Humanities/Faculty of Education Research Day, University of Western Ontario

August 7, 2008

- How Georeferences in Library Classifications and Bibliographic Attributes in MARC Can Be Used to Crystallize Knowledge About Library Collections? Tenth International Society for Knowledge Organization Conference “Culture and Identity in Knowledge Organization”, Montreal, QC

July 7, 2006

- Uncovering Hidden Clues about Geographic Visualization in LCC. Ninth International Society for Knowledge Organization Conference, Vienna, Austria

November 7, 2006

- MLIS 505A 002 Information Systems and Technology. Lecture “Introduction to Information Retrieval” and “XML and Applications.”

November 2, 2002

- Integration of Knowledge Organization Systems into Digital Library Architectures. Advances in Classification Research, 13th ASIST SIG/CR Workshop on "Reconceptutalizing Classification Research", Philadelphia, PA

SERVICE

To the profession

- Reviewing for journals, books Journal of Digital Information, Indexing and Retrieval of Non-Text Information (book).

To the Faculty of Information and Media Studies, University of Western Ontario

2008 – 2009

- Committee Member, LIS Doctoral Program Committee

2008 – 2009

- Committee Member, Appointments Committee

2008 – 2009

- Vice-President, Library and Information Science Doctoral Students Association

CONTINUING PROFESSIONAL DEVELOPMENT

Health Information Science Inaugural Symposium, University of Western Ontario □ September 16, 2011

PROFESSIONAL MEMBERSHIPS

American Society for Information Science & Technology (ASIS&T) □ 2002-Present

International Society for Knowledge Organization (ISKO) □ 2006-Present

Association for Computing Machinery (ACM) □ 2011

Networked Knowledge Organization Systems/Services (NKOS) □ 2003-Present